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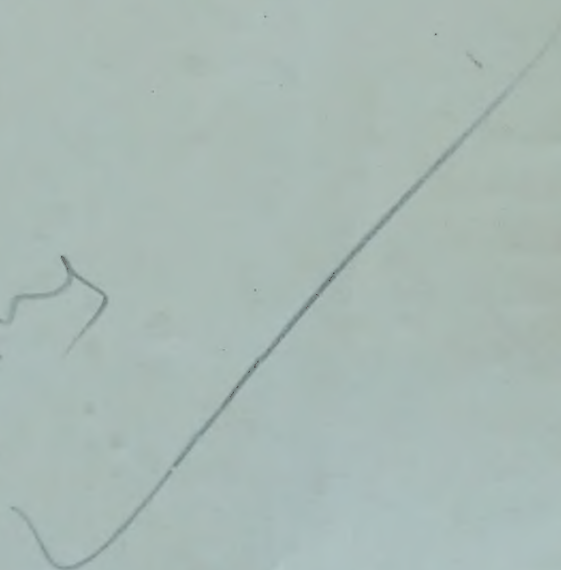
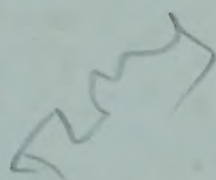
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Rosenau Prevent















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PREVENTIVE MEDICINE  
and  
PUBLIC HEALTH







R O S E N A U

# PREVENTIVE MEDICINE

AND

# PUBLIC HEALTH

KENNETH F. MAXCY, M.D., DR. P.H., Professor Emeritus of  
Epidemiology, The Johns Hopkins University, School of Hygiene and  
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*With 27 contributing authors*

*EIGHTH EDITION*



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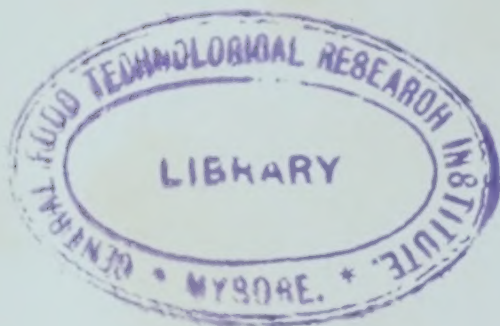
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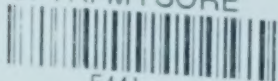
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## Preface

With publication of this new eighth edition of Rosenau, which has come to be regarded as a classic in its field, we are retitling it in the belief that the word *Hygiene* no longer connotes its range, and that this new title, *Preventive Medicine and Public Health*, will more adequately indicate the scope and purposes of the book which are unchanged.

The subject matter has been critically reviewed and revised in the light of recent findings by each contributing author whose name appears with his section. The editor is responsible for the remainder. To bring the book up to date, 634 pages, or 44 per cent, of the text in the previous (1951) edition have been rewritten either completely or in part. Recent figures have been incorporated in the text and statistical tables. Where recent contributions have advanced knowledge or concepts during the past five years selected references have been added to document the work and afford the reader opportunity to pick up the thread of current investigations or changes. The index has been greatly enlarged and it is more detailed in its coverage.

To understand the selection of subject matter it is necessary to know the past history of this book. When the first edition was published in 1913, Dr. Milton J. Rosenau, then Professor of Preventive Medicine at the Harvard Medical School, opened his preface with the following words: "This book has been written in response to a demand for a treatise based upon modern progress in hygiene and sanitation. The work is planned to include those fields of the medical and related sciences which form the foundation of public health work. So far as I know no other book on the subject covers the broad field considered in this volume. The progress in hygiene and sanitation has been so rapid that the subject of preventive medicine has become a specialty, and its scope has become so broad that the question throughout the making of this book has been rather what to leave out than what to include. The facts here brought together are widely scattered in the literature and many of them difficult of access; they have been collected for the student of medicine and the physician, as well as those engaged in sanitary engineering or public health work."

In five subsequent editions, with the help of collaborators, Dr. Rosenau kept up with the progress in this rapidly developing field. His sixth and last edition was published in 1935. Approaching the end of a rich and fruitful career, he thought that it was time the burden be passed on to some younger colleague. So it was that this textbook came under the present editorial supervision and the seventh edition appeared in 1951. In the sixteen years that had elapsed since publication of the sixth edition by Rosenau there had been remarkable scientific and practical advances in the field of public health and preventive medicine. While it was possible to retain some parts of the old text with little change, it was necessary to revise or rewrite large parts and to introduce much new material. Furthermore, to fulfill its function adequately it was necessary to enlist collaboration with a wider range of specialists. So the seventh edition became a joint contribution of some 27 authors. Inevitably, there was some overlapping of subject matter, but effort was made to

## PREFACE

reduce this to a desirable minimum by cross references in the text, emphasizing interrelationships.

Grateful acknowledgement is made of the assistance rendered by collaborators in bringing about this revision. I am immeasurably indebted to Mrs. Margaret R. McConnell whose efficient editorial assistance has made this edition possible. I wish also to thank Mrs. Hermine Bird for reading proof and checking references. Finally, it is a pleasure to again express my appreciation to Appleton-Century-Crofts, Inc., particularly to Mr. George A. McDermott and his staff, for constructive interest and editorial guidance.

. KENNETH F. MAXCY



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PREVENTIVE MEDICINE  
and  
PUBLIC HEALTH





## Section One

# PREVENTION OF COMMUNICABLE DISEASES

## 1

### CONTAGIOUS DISEASES SPREAD LARGELY FROM THE MOUTH AND NOSE

The beginnings of hygiene can be traced back to antiquity in the sanitary laws of the Hebrews. Preventive medicine began with the first primitive idea of contagion. Even in the time when epidemics were explained as due to the wrath of the gods or visitations of evil spirits, it was observed that certain illnesses apparently spread from person to person. Gradually, the idea of contagiousness was associated with a number of diseases. Fracastorius, in his book *De Contagione*, published in 1554, proposed a classification of diseases into those which were contagious and those which were not. For three centuries following this publication the medical profession was divided into two camps: the non-contagionists, who believed that the causative agents of epidemic disease were inanimate and gaseous in nature and associated with emanations from decomposing organic matter, effluvia and miasma; and the much smaller group, the contagionists, who identified contagiousness with germs of some kind.

Looking backward, this confusion is understandable. That some diseases were contagious was fairly obvious, but some apparently arose spontaneously without a traceable source. The confusion was finally resolved in the latter part of the nineteenth century by the work of Pasteur, Koch, and their followers. The causative relationship of specific micro-organisms for one after another of the infectious diseases was established and the part played by carriers, missed cases, common water and food supplies, arthropod vectors, and animal reservoirs in transmission was gradually elucidated.

With these advances in knowledge came the vision of the possibilities of prevention of disease by community measures. Health departments were organized very largely for the purpose of controlling the spread of communicable diseases by isolation and quarantine, sanitation, immunization and diagnostic services. It was not until after the turn of this century that they became concerned with the broader aspects of preventive medicine. It is appropriate, therefore, that this book begin with a discussion of communicable diseases. Furthermore, it is also appropriate, since our interest is primarily in prevention, to classify these diseases on the basis of the principal mode of transmission. The first to be considered and most important from the point of view of the mortality and morbidity which they cause the world over, are those contagious diseases spread largely by discharges from the nose and mouth. While alike insofar as they are caused by microparasites which enter and leave the human host through the respiratory tract, they differ in many ways. These invaders are of various genera and species: viruses, rickettsiae, bacteria and fungi. There is a wide range in their potential pathogenicity both for the individual and

for the community. Each has its own distinct clinical, pathological and epidemiological pattern, determined by the peculiar biological relationships of the specific causative microparasitic species or race to the human host on the one hand and to environmental conditions on the other. With each, understanding of these relationships is essential to effective measures of control. Such generalizations as can be drawn regarding methods directed toward reduction in the spread of respiratory or air-borne infections will be discussed in a later chapter.

## SMALLPOX

(*Variola*)

Smallpox is an acute exanthematous fever. Onset is sudden with pyrexia, headache, backache, pains in the limbs, vomiting. In severe cases prodromal rashes, erythematous or petechial, may appear. On the second to the fifth day characteristic eruption begins to develop, the temperature falls, and the constitutional reaction abates. The eruption is general and may occur on all parts of the skin and exposed mucous membranes. It comes out in a single crop as maculopapules, which develop into vesicles, and these into pustules which dry and crust. Pocks are most numerous on the face, forearms, wrists, palms of the hands, and soles of the feet. During the pustular stage of the eruption the temperature may rise again. Four clinical types are recognized: (1) discrete, (2) confluent, (3) hemorrhagic (including the highly fatal hemorrhagic pustular form and the uniformly fatal purpuric form), and (4) modified.

The period of incubation has a mean of 12 days, although variations from 7 to 21 days have been noted. Usually, 14 days elapse between exposure and appearance of the eruption.

Two types are now recognized. The classical or true smallpox is called *variola major*. Its severity varies from time to time and in different geographical areas, the case fatality rate ranging from about 5 per cent to 40 per cent or more. During the epidemic at Minneapolis, affecting 571 persons, Sweitzer and Ikeda (1927) reported the following death rates in the clinical varieties observed: among 225 cases with discrete eruption 14, or 6 per cent, died; among 151 cases with confluent eruption 68, or 45 per cent, died; among 144 cases of the hemorrhagic type 113, or 78 per cent, died; of 51 cases classified as *variola purpurica* all died.

Since the latter part of the nineteenth century a mild type of smallpox has been described under many names—*alastrim*, *Katfir-pox*, *amaas*, *milk-pox*. It is now recognized as *variola minor* (Marsden, 1948). It may closely simulate chickenpox, from which it can be differentiated at times only by laboratory procedures (see page 24). It is almost never a cause of death by itself.

Recovery from a clinical attack of smallpox is followed by an immunity that is usually lifelong. Second attacks in the same individual are extremely rare.\* *Variola major* affords immunity to *variola minor* and vice versa.

Prevalence. It is difficult for us now to realize that smallpox was once as common as measles and much more fatal. Many of those who recovered were disfigured for life, left blind, or left with some other serious consequence of the disease. For

\* Jenner mentions "the lady of Mr. Gwinnett, who has had smallpox five times," in *Bacon's Life of Jenner*, vol. II, page 265. Louis XV of France died of a second attack.



centuries, smallpox was one of the greatest scourges. It depopulated cities and exterminated tribes. In Europe alone, where its ravages were comparatively slight, it killed hundreds of thousands yearly. In the eighteenth century, of which we have the best records, almost everybody had it before he grew up. Parents often exposed their children to the disease in order to be through with it, just as they now sometimes do with the minor contagious diseases. In China, a mother does not number among her children those who have not yet had smallpox, because she well knows how uncertain will be their stay in the family.

Smallpox was introduced into the Western Hemisphere by the Spaniards about 15 years after the discovery of America. In Mexico, within a short period, 3,500,000 persons are said to have died of the disease. Catlin in 1841 stated that of 12,000,000 American Indians, 6,000,000 fell victims to smallpox. In Iceland, in 1707, 18,000 perished out of a population of 50,000; that is, smallpox killed 36 per cent of the total population in one year.

Up to the end of the nineteenth century, true virulent smallpox (*variola major*) was the prevalent type in most countries of the world. It is still propagated in limited geographic areas of Asia, Africa and South America. Gradually, however, *alastrim* (*variola minor*) has become more and more widely disseminated (Hedrich, 1936). According to Chapin and Smith (1932) it made its appearance in the United States at about the time of the Spanish-American War, presumably being introduced by way of the West Indies from Africa. In most of the years since, while the number of reported cases has been large, the fatality rate has ranged from 0.69 to 0.29 per cent (Dauer, 1940). From time to time, however, in this country as in others this experience has been punctuated by the occurrence of sharp outbreaks characterized by a high fatality rate. These have originated through importation. They are usually traced to an unrecognized case recently arrived from another country. For example, the epidemic of 1924-1925 was traced to two tramps and a boy who were infected with malignant smallpox in Winnipeg, Manitoba, in January, 1924. They carried the disease to Duluth, Minnesota, to Detroit, Michigan, and to New Britain, Connecticut. From these centers it radiated, causing 74,000 cases and 1,270 deaths. More recently, an outbreak of *variola major* in the State of Washington was traced to the arrival of a ship from the Orient with cases of malignant smallpox on board (Palmquist, 1947). In the same year a virulent strain was introduced into New York City by a traveler coming from Mexico (Weinstein, 1947). Similarly instructive is the outbreak in Scotland in 1942 (Macgregor and Peters, 1942).

With advance in public health administration and preventive medicine, conditions are now unfavorable to continuous propagation of smallpox in many countries (WHO, 1951). No outbreaks have been reported from Pacific Oceania for the past decade. The continent of Europe, with the exception of Portugal, shelters no endemic focus but is repeatedly and constantly threatened with importations of the disease by land, sea and air travelers. The same may be said for the British Isles, Canada and the United States. In this latter country, the number of reported cases has decreased from 48,907 in 1930 to 39 in 1950.

**Pathogenesis.** Downie (1951) has recently reviewed evidence on which the present day concepts of pathogenesis of smallpox are based. It is still not possible to

## DISEASES SPREAD FROM THE MOUTH AND NOSE

give a detailed account of the course of events which follow human infection with the virus of smallpox. Nevertheless, the outline of the story seems fairly clear.

Table 1-1. Smallpox in the United States, 1900-1950

Year	Number of Cases *	Number of Deaths *	Case Fatality Rate Per Cent	Year	Number of Cases *	Number of Deaths *	Case Fatality Rate Per Cent
1900	21,064	894	4.24	1925	40,281	724	1.79
1901	62,374	1,376	2.20	1926	32,694	387	1.18
1902	72,946	2,510	3.44	1927	37,977	151	.39
1903	52,737	1,580	2.99	1928	39,396	141	.35
1904	31,697	1,282	4.04	1929	42,282	179	.42
1905	19,417	406	2.09	1930	48,907	182	.37
1906	15,223	90	.59	1931	30,151	108	.36
1907	18,977	96	.50	1932	11,194	50	.44
1908	33,998	108	.31	1933	6,491	39	.60
1909	23,560	155	.65	1934	5,371	24	.44
1910	31,254	429	1.37	1935	7,957	25	.31
1911	23,044	174	.75	1936	7,834	35	.44
1912	23,566	305	1.29	1937	11,673	34	.29
1913	38,400	259	.67	1938	14,939	46	.31
1914	40,474	216	.53	1939	9,877	38	.38
1915	38,381	247	.64	1940	2,795	14	.61
1916	19,740	247	1.25	1941	1,374	12	.87
1917	47,508	320	.67	1942	863	2	.23
1918	80,334	414	.51	1943	733	8	1.09
1919	62,876	327	.52	1944	390	9	2.31
1920	110,672	492	.44	1945	349	12	3.44
1921	108,487	758	.69	1946	333	25	7.50
1922	33,305	901	2.70	1947	169	5	2.95
1923	30,890	165	.53	1948	56	5	9.00
1924	56,512	896	1.58	1949	56	2	3.57
				1950	39	0	0

\* Data from 1900 to 1928 from Chapin, C. V., and Smith, J., *J. Prev. Med.*, 6:273, 1932. Data from 1929 to 1939 from Dauer, C. C., *Pub. Health Rep.*, 55:2303, Table 1, 1940. Data from 1940 to 1950 from Public Health Reports.

The site of entry of the virus is to the tissues of the upper respiratory tract. At most, only a minimal or closed lesion occurs in the mucous membrane, and the virus quickly passes to lymphatic glands and by blood stream to internal organs. Progressive infection of cells in these organs, with multiplication of the virus, takes place during the incubation period. Toward the end of this period or at the onset of illness there is an overflow of virus into the blood stream (viremia). The transient viremia leads to widespread infection of the skin, mucous membranes and other tissues, although lesions do not become apparent in the skin for a further two to three days. As these lesions break down, liberating virus on the surface, the patient becomes infective for others. The immune response with formation of antibodies follows. The rapidity and extent of the antibody formation determines the extent of the rash and the severity of the disease. The maturation of the eruption proceeds after the antibodies have appeared and is secondary to the destruction of cells infected in the first few days of illness. Persons who die in the later pustular stage of the eruption may have a high titer of antibody in their sera; in such persons death is due to the late effects of earlier virus activity or to some complicating disability or



infection. Antibodies persist at a high level for some years after clinical recovery. Rarely, there are individuals (usually partially protected by previous vaccination) in whom the mobilization of antibodies is so rapid that they have a very brief illness without eruption, *variola sine eruptione*. Transplacental infection of a fetus in utero of an expectant mother who develops the disease may occur as a sequel of the viremia. Whether an attack of smallpox in the early months of pregnancy may be a source of fetal defects, as in rubella, is unknown.

**Mode of Transmission.** Smallpox is preeminently a contagious disease of man. It is propagated by some form of human contact, direct or indirect, from an infected to a susceptible individual. The virus makes its exit from the infected host through the lesions in the mucous membrane of the mouth and pharynx and through the lesions of the skin. While most infectious during the early eruptive stage, the period of communicability is regarded as lasting from the onset of illness to the complete exfoliation of crusts and scabs. Direct transmission for short distances may occur through projection of droplets or droplet nuclei from the upper respiratory tract of an infected host. Indirect transmission takes place through contamination of bed clothes and other articles in the patient's surroundings. Dried infective material may be resuspended as air-borne dust particles (Downie and Dumbell, 1947). Ordinarily the range of infectiousness is limited to the vicinity of the infected individual. Instances have been reported in which an apparently healthy person conveyed the virus, but subclinical or inapparent infections are comparatively rare.

Smallpox is occasionally transmitted by accidental inoculation of the abraded skin of a susceptible individual with infectious material from a patient. The protopapules (of Ricketts), usually situated on the face, are recognized on account of the larger size and more advanced development than the remaining element of the general eruption, which they commonly precede by several days.

**Variola Virus.** Three major types of the variola-vaccinia virus group are recognized: (1) *variola major* or smallpox, (2) *variola minor* or alastrim, and (3) vaccinia or cowpox. They are closely related and have essentially the same physical characteristics and properties, yet they are readily distinguished by the reaction which they produce in man and in experimental animals. The first two can, by persistent effort, be transformed into the third by animal passage.

In suspensions prepared from tissues infected with variola-vaccinia virus small granules can be demonstrated, known variously as elementary bodies, E.B.'s and Paschen bodies, which have been shown to be aggregates of virus molecules.

Guarnieri in 1892 described the bodies which now bear his name in the deep epithelial cells of the skin in cowpox and smallpox, as well as in the epithelial cells of the cornea of rabbits. These intracellular inclusion bodies are now accepted as being quite specific. They can be demonstrated in all types of infection with the variola-vaccinia virus. They are probably masses of elementary bodies held together by a matrix.

Variola virus is quite stable. In dried state it may retain its viability for some time. Thus, Downie and Dumbell (1947) found that desquamated crusts which were stored for a year in a stopped bottle at room temperature contained viable virus. This stability facilitates diagnostic studies, since material for examination can be shipped without refrigeration. On the other hand, infectivity of variolous crusts suspended in Locke's solution is destroyed by heating at 55° C for 20 minutes or at

37° C for 24 hours. The virus is quite resistant to desiccation and cold. It is rapidly destroyed by exposure to sunlight or ultraviolet rays. It is not so easily killed as are nonsporing bacteria by many of the chemical germicides in common use.

**Laboratory Diagnosis.** Laboratory methods are invaluable in confirming the clinical diagnosis of smallpox. This may be accomplished by identification of the virus or its antigens in material derived from cutaneous lesions early in the course of the disease or the demonstration of specific antibodies in the serum obtained late in the disease or during convalescence. Antibodies may be demonstrated by various techniques: by complement fixation, by tests for inhibition of virus hemagglutinin, or by various types of tests to measure the power of serum to inhibit or neutralize the infectivity of the virus. The procedures generally employed are given in detail by Parker (1948). In brief, those found most useful are the following:

1. Smears are obtained by scraping the base of papules or vesicles and transferring the material to stained glass slides. The preparation is fixed, stained and examined with a microscope for elementary bodies.

2. Material for test is obtained by washing the scrapings from the base of the papule with a scalpel into a small quantity of physiologic saline solution or by a preparation of vesicular or pustular fluid collected in capillary tubes. A 10- or 11-day-old chick embryo is inoculated with a suspension of suspected material dropped onto the surface of the chorioallantoic membrane. The egg is incubated for three days and then examined for characteristic lesions produced by variola. To confirm the identification the infected membrane should be suspended in saline solution for further passage in the chick embryo and for inoculation of rabbit skin and rabbit cornea (the Paul reaction). The virus originating in man giving discrete lesions on the chorioallantoic membrane of chicks, producing keratitis in rabbits with Guarnieri bodies in corneal cells and producing inconsequential or no lesions on rabbit skin may be considered variola.

3. Variola antigen in a lesion may be identified in a complement-fixation test using hyperimmune rabbit serum as a test reagent. The antigen is prepared by extracting smears of pustule fluid or crusts.

4. Using variola antigen prepared by egg culture, serum from the patient is tested for complement-fixing antibodies early and late in the course of the disease.

Downie, McCarthy and MacDonald (1952) assessed the value of these four methods of diagnosis in an epidemic of alastrim. Specimens were received from 154 patients and in 87 the diagnosis of alastrim was made by one or more tests. They point out that the clinician should not consider diagnosis of alastrim to have been excluded when he receives a negative report on stained smears. Both the complement-fixation test for alastrim antigen and the egg culture method are extremely reliable, provided there is sufficient material for examination. A test for specific antigen can provide a result within a day or two of taking the specimen, while egg culture, although slow, is probably the more conclusive. Complement-fixation tests for antibodies in the patient's serum are of value only when the patient has been ill for some 10 days and are used chiefly in atypical missed cases when the lesions have healed.

**Treatment.** None of the recently developed antibiotic drugs has been demonstrated by critical trial to be effective in the treatment of smallpox virus infection.



They may be of some value in suppressing secondary bacterial invasions which may complicate the clinical course of the disease.

**Prevention and Control.** From the point of view of the individual, there is only one way to prevent smallpox, and that is through vaccination. The method is logical, specific, sensible, and satisfactory.

There is only one way to prevent the epidemic spread of smallpox in a community and that is by maintaining at all times a high degree of immunity through routine vaccination of all infants and revaccination of young children on entering school. The entire population should be revaccinated when the disease appears in severe form.

Control of spread in a community in which there is a considerable proportion of susceptible persons depends primarily upon the early recognition, reporting, and isolation of the first case or cases to appear. All who have been in contact with a case since the onset of symptoms should be detained pending establishment of immunity. They should be vaccinated with virus of full potency and kept under daily observation until the reaction has passed its maximum intensity, if the vaccination has been performed within 24 hours of first exposure and the strain of smallpox was of *variola minor* type; otherwise, for 16 days from the date of last exposure. To erect a barrier of immunes, as many persons as possible living or working in the environment of each case should be vaccinated.

Since the virus is an obligate human parasite and can survive only a short time under conditions outside the human body, attempt should be made to trace the source of every case. The infection must have originated from contact with an individual who has had the disease in recognized or unrecognized form. Particularly with alastrim is it necessary to investigate cases of supposed chickenpox associated in time or place, and to review carefully for error of diagnosis.

## VACCINATION AND SMALLPOX

**Historical Note.** The credit of giving vaccination to the world is due to Jenner (1798), who through logical and scientific methods proved that a person who has had the mild disease cowpox enjoys protection against the serious disease smallpox. This fact had been known to some of the farmers and folk of England for a long time. But it was Jenner who first put this vague belief upon a scientific basis.

Jenner made his crucial experiment May 14, 1796, when he transferred vaccine material from the hand of a dairy maid (Sarah Nelms), who was infected with cowpox and who had scratched her hand with a thorn, to the arm of a boy about eight years old (James Phipps). A typical take followed. On July 1 Jenner inoculated the boy with variolous matter, but no disease followed. Several months later he again inoculated the boy, with the same results.

In addition to such direct experimental proof, Jenner inoculated smallpox matter into 10 persons who had at some previous time contracted cowpox and found that they were resistant to smallpox. Jenner himself was inoculated when a boy. The question of "inoculation" (with smallpox) as contrasted with "vaccination" (with cowpox) will be discussed presently.

In 1796 Jenner presented the results of his observations to the Royal Society, but the paper was refused. He then published it in 1798 as a book, "An Inquiry

into the Causes and Effects of the Variolae Vaccinae, a Disease Discovered in Some of the Western Counties of England, Particularly Gloucestershire, and Known by the Name of the Cowpox.\* This book is one of the medical classics, and it should be read in the original by every student of preventive medicine.

In America, the first vaccination occurred on July 8, 1800, when Benjamin Waterhouse of the Harvard Medical School vaccinated his five year old son. After his son and two slaves were successfully vaccinated with cowpox, they were inoculated with smallpox with negative results.

In Boston in 1802 an experiment involving the vaccination and subsequent inoculation of 19 boys took place. This was one of the most crucial experiments in the history of vaccination, and it justified the conclusion of the Board of Health: "Cowpox is a complete security against the smallpox."

Jenner established a fact. A century later Pasteur, impressed with this fact, expanded it into an immunological principle.

### VACCINATION

**Definition.** Vaccination consists in introducing vaccine virus into the skin with the object of inducing cowpox (*vaccinia*) in order to prevent smallpox (*variola*). Vaccine virus contains the active living principle of cowpox. The vaccination or "take" should be regarded as successful only when the course is characteristic. Primary takes occur in persons who are susceptible; modified reactions are indicative of immunity and occur in persons who have previously been vaccinated or who have had smallpox.

For over 80 years vaccination (from *vacca*, a cow) was a specific term limited to the introduction of the virus of cowpox into the skin in order to induce vaccinia and prevent variola. Since the time of Pasteur,\* however, the term has been used in a generic sense to include the introduction of many different substances in many different ways and for many different purposes.

**First Vaccination (Primary Take). COURSE OF THE ERUPTION.** The period of incubation is about three days, when a papule appears upon the skin where the vaccine virus was inserted. The papule develops into a vesicle and this in turn into a pustule, which dries, crusts, and rapidly heals. The papular, vesicular and pustular stages follow each other in orderly succession.

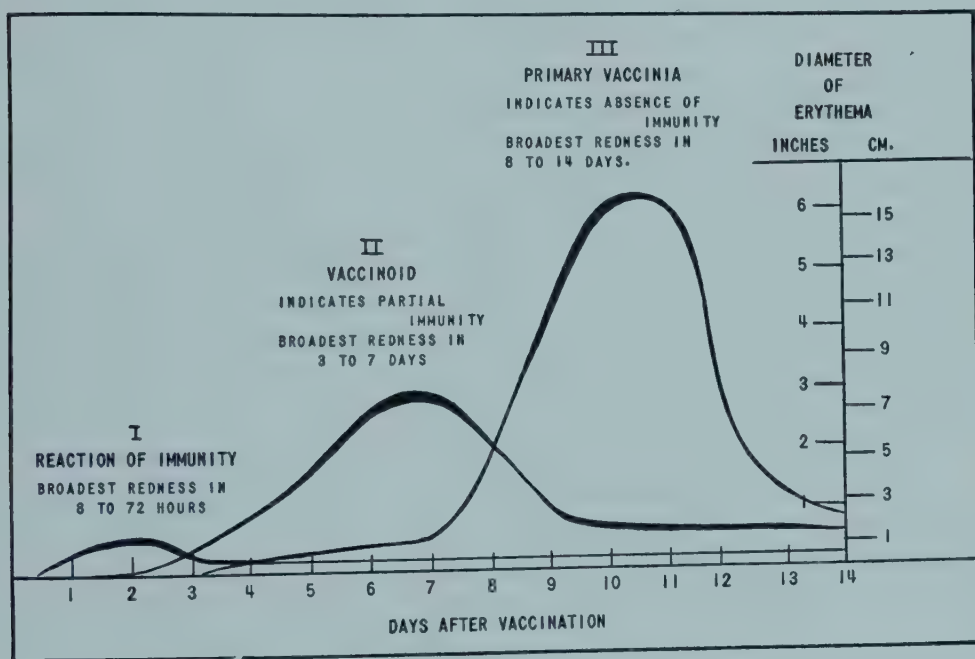
The *papule* is small, round, bright red and hard, but superficial. It appears in about 72 hours. On the fifth day the top of the papule becomes vesicular. The development is rapid so that by the sixth day the papule, which continues to grow, has almost changed to a vesicle. On the seventh day, the vesicle is fully developed and characteristic. It is round, umbilicated, multilocular, with water-clear content—the lymph. The remains of the papule persist as a deep red ring at the periphery of the vesicle and extending out from this there now appears a reddened inflamed area, known as the areola. The stretched epidermis covering the vesicle has a glistening white sheen. This gives the picture of "the pearl upon the rose leaf" which constitutes the true Jennerian vesicle. The development continues so that by the next day (eighth) the vesicle is larger and fuller and the umbilication almost disappears. The

\* Pasteur said of his immunization against anthrax and chicken cholera: "I have given to the word vaccination an extension which I hope science will consecrate as an homage to the name and immense services rendered by Jenner." Valéry Radoy, *Life of Pasteur*, American edition, p. 332.



contents is becoming turbid and the areola is larger. On the ninth day "secondary umbilication" occurs because the vesicle is flattened and less full. By the tenth day the vesicle has turned to a pustule, which develops gradually in size but retains the characteristic round, flat, umbilicated shape. The areola continues to grow. The pustule reaches full development and maximum size on the twelfth day, after which it rapidly dries, the areola fades, and the swelling subsides soon leaving a hard brownish scab or crust which should not be removed. It drops off spontaneously about the twentieth day or later. The scar is at first red and finally turns white, with the pits or foveations so characteristic of the pock mark.

**Modified Reactions and Revaccination.** Although all gradations are found in practice, reactions following vaccination may be classified into three categories according to their characteristics (Leake, 1939), as shown in the accompanying schematic representation (Fig. 1-1).



From Leake, J. P., Pub. Health Rep., Spec. Rept. No. 1137, 1939.

Fig. 1-1. The three types of reaction following vaccination; the height of the curves on different days indicates the diameter of the erythema.

(1) *Primary vaccinia* or the typical vaccination reaction can occur only in an individual who is susceptible to vaccinia and to smallpox. Whatever immunity they may previously have possessed as a result of a vaccination many years before or an attack of smallpox has been lost.

(2) *Vaccinoid* or accelerated reaction. In an individual who has lost part of the protection gained from a previous vaccination or attack of smallpox, the maximum diameter of the erythema is reached in three to seven days. The papule progresses to the formation of a vesicle or vesicles. These may be so minute that they can be seen only with the aid of a magnifying lens; they may dry and disappear rapidly, or they may coalesce and closely simulate the lesion produced in primary vaccines, running a more rapid course to scab formation.

(3) *Immediate reaction* or reaction of immunity. In an individual who is fully protected against smallpox by a previous vaccination or a previous attack of smallpox, the maximum diameter of the erythema is reached and passed in 8 to 72 hours. There is usually enough reaction to constitute a papule, but no vesicle formation.

In making these interpretations regarding the immunity status of an individual who has been vaccinated, due consideration must be given to certain qualifications. The first and most important of these is that immunity can be judged from the type of reaction only if vaccine of full potency \* was used and inserted intradermally by the multiple pressure or scratch method. If the vaccine used has been weakened by time or temperature, the reactions produced will be modified. Vaccinoid reactions may give at early inspection (third day) an appearance similar to that of the immediate reaction. Even if an early reaction is seen, subsequent observations, about the third and ninth days, are necessary to determine whether the reaction was that of immunity, vaccinoid, or vaccinia. Trauma due to the mechanical act of vaccination by the scratch method may cause enough irritation so that redness persists at the time of the 48-hour observation independently of any specific reaction. This is largely avoided if the multiple pressure method of insertion is used. Every vaccination should give a reaction of some type.

McKinnon and Defries (1931) have emphasized that the immediate or early response is not necessarily an indication of immunity. They suggested that it is in reality an indication of allergy to the vaccinia antigens. Craigie and Wishart (1933) studied the human skin sensitivity to washed and killed suspensions of vaccinia elementary bodies. When such a preparation was inoculated intradermally into previously vaccinated individuals an early or immediate reaction usually occurred, whereas in the unvaccinated individual no such response could be elicited. They pointed out that allergy and immunity to vaccine virus are not necessarily related, except in so far as they have common origin in a previously immunizing reaction.

On the other hand, Leake called attention to the fact that the usual reactions of sensitivity as shown by skin tests are rapid, appearing and reaching their maximum within about one-half hour. The fact, however, that reactions otherwise indistinguishable from the immediate reaction to living vaccine may be given by heated vaccine, indicates that at least part of the visible phenomenon which is called the reaction of immunity is given by inactivated antigenic material. If a fully potent vaccine has been used and the insertion has been adequate to produce any reaction whatever after two days, other than the reaction due to trauma, one may conclude that even though this may be due to allergy, or the beginning of a vaccinoid reaction, or the beginning of a primary vaccinia, full immunization is assured by the time the reaction reaches its maximum.

The nature of the modification seen in those who have had smallpox varies with the capacity of the individual to retain immunity. If the interval is less than five

\* A lot of vaccine virus can be regarded as of full potency when, properly applied, it gives 100 per cent of vaccinias (typical primary successes) in every application on at least 100 previously unvaccinated individuals. Leake (1939) suggests that a more practical test is that it should give more than 50 per cent of vaccinoid reactions (accelerated) in unselected persons who have been vaccinated or have had smallpox over 10 to 40 years previously, and on a smaller group, perhaps twenty to fifty persons, will give a good idea of the potency of eruption. Using this criterion trial a batch of vaccine. On rabbits 1:3,000 dilution superficially applied should give a confluent



years, revaccination is apt to give an immediate reaction; between 5 and 20 years there is usually an accelerated reaction; after longer periods of time revaccination may run the course of a primary take. This time correlation applies only in the aggregate, for individual cases vary greatly.

**Methods of Vaccination.** **AGE.** The best time to vaccinate is during the first year of life, but avoiding the summer. There are no contraindications to vaccinating babies shortly after birth, but successful takes are somewhat less frequent than at six months. Vaccination at the age of six months usually proceeds with little or no fever or discomfort. In infants the constitutional reaction from first vaccination is usually much less than in older children and adults, and the risk of complications is practically eliminated. If the infant is to be immunized against diphtheria also, this procedure should be undertaken first and vaccination follow after an interval of several weeks.

Since immunity decreases with the lapse of time revaccination is necessary to afford continued protection. There is some difference of opinion as to just when it is best to vaccinate the second time, but it is generally considered advisable at the time of entering school.

**SITE.** The outer surface on the left arm at the insertion of the deltoid muscle is the most convenient for the operator and the patient. This is the original site selected by Jenner. It is easily kept cool and dry, and is desirable because of the character of the lymphatic drainage. The skin here is easily made taut during the process of insertion by grasping the under side of the arm. Inspection of the course of the local reaction is also facilitated.

Any part of the skin or exposed mucous membrane is susceptible; a take will follow the accidental insertion of the virus into the conjunctiva or the lip.

The leg is sometimes selected to avoid visible disfigurement. With small insertions on the arm, as now practiced, the resulting scar is small, definite and typically pitted, but not disfiguring. The leg is more exposed than the arm to warmth, moisture, and street dust. On account of blood stasis, primary leg vaccinations are often accompanied by purplish discoloration and result in a large, slowly healing ulceration; they usually cause temporary disability. For these reasons this site should be avoided.

The skin at the site of insertion should be surgically clean. Sponge with acetone or alcohol and wait until it evaporates. Do not use denatured alcohol or nonvolatile germicides for they are apt to injure the virus and prevent successful takes. Acetone is an efficient cleanser, is cheap and evaporates rapidly.

Handle the capillary tube containing the vaccine with aseptic precautions and place its contents upon the prepared skin in one small droplet.

**INSERTION.** The objective is to bring the vaccine into contact with the columnar epithelium or basal cells in the lower layers of the epidermis. The injection should be intradermal. Under no circumstances should the vaccine be placed subcutaneously.

*The Multiple Pressure Method* (Leake, 1939). The needle, which should be new, sharp, and sterile, is not thrust into the skin, but is held almost parallel or tangential to it, with the forefinger and middle finger of the right hand above the needle and the thumb below, the needle pointing to the operator's left. The needle should be crosswise of the arm, so that the thumb of the operator is not impeded by hitting the skin. The *side* of the needle point is then pressed firmly into the drop

about 30 times within five seconds (or ten times for primary vaccinations with highly potent vaccine), the needle being lifted clear of the skin each time. This rapid up-and-down motion of lifting the needle and pressing it against the skin should be quite perpendicular to the skin and needle, and not in the direction of the long axis of the needle. The point is not driven into the skin, but at each pressure the elasticity of the skin will pull a fraction of an inch of the epidermis over the point of the needle so that the vaccine is carried into the deeper layers of the epidermis, or just beneath these layers, where multiplication of the virus takes place most easily. The insertion should be confined to an area not more than one-eighth inch (3 mm.) in its greatest diameter. No signs of bleeding should occur and all evidence of the trauma should fade out in a few hours. Immediately after the pressures have been made, the remaining vaccine is gently wiped off the skin with sterile gauze and the sleeve pulled down, the whole operation of pressing and wiping taking less than 10 seconds.

*The Scratch Method.* With a sterile needle make a light scratch one-eighth inch (3 mm.) long, starting in the droplet of vaccine. Only one scratch should be made and it should not be deep enough to draw blood, but a little oozing will do no harm. The excess is allowed to dry in place or is wiped away with sterile gauze. A control scratch is not necessary but is useful for purposes of interpretation and teaching.

*The Intradermal Injection.* For this method a sterile accurately graduated (tuberculin) syringe with a 26 gauge needle is required. About 0.1 ml. of a 1:40 dilution of glycerinated calf vaccine or properly diluted culture vaccine is injected intradermally. The principal objections to the method are the more elaborate materials required, and the greater danger of depositing the vaccine subcutaneously rather than intracutaneously. Subcutaneous applications of smallpox vaccine give reactions which are different from those described as resulting from the intracutaneous, scratch or multiple pressure introduction.

*Scarification.* This consists in rubbing the virus into an abraded surface produced by multiple scratches close together, or by cross hatching. This method is dangerous and should be prohibited.

**AFTER CARE.** Avoid the action of direct sunlight during or immediately after vaccination because of its possible attenuating effect upon the virus deposited in the superficial layers of the skin. Keep the vaccinated area dry, cool and clean. Bathing need not be omitted nor any of the ordinary occupations, but care should be taken not to soften the crust with water or sweat. Unnecessary use of the arm must be guarded against, as this increases the congestion. Vaccine vesicles should be let alone. They should not be opened. Abrasion by clothing or any other form of irritation should be avoided. The vesicles should not be anointed or treated.

No dressing of any kind should be fixed to the vaccination site, but several layers of dry sterile gauze, attached to the inside of the sleeve rather than to the skin, do no special harm provided they are renewed frequently. Shields and pads of any sort are unsafe because they favor softening, breaking down, and secondary infection of the vesicle. If the pustule breaks, or the crust comes off, or the take shows indications of secondary infection, the wound should be treated surgically as an infected wound. The site should be inspected frequently enough to determine whether the take is running a characteristic course.



To summarize, the four most important factors in safe and successful vaccination are the use of a fully potent vaccine, clean technic, restriction of the insertion to a very small and superficial area, and insuring the rapid drying of the vesicle.

**Immunity Conferred by Vaccination.** The specific immunity conferred by vaccination against smallpox appears about the eighth to the eleventh day, that is, about the time at which the areola has reached its height. Since the incubation period of smallpox is frequently 12 days or more, a successful vaccination performed within 24 to 48 hours of the time of exposure to a case can be expected to prevent attack; within two to eight days it may prevent or attenuate the attack; later the vaccination and the smallpox eruption develop concurrently and independently. For protection to be certain the areola of the vaccination should have reached its height before the exposure to smallpox occurs.

The duration of the immunity varies with individuals. Studies based on the reactions following revaccination indicate that the immunity produced by a primary take will, with extremely rare exceptions, protect against vaccinia, and, therefore, against smallpox, for from two to ten years. A few individuals may be protected for a longer time. After revaccination (secondary stimulation) the duration is indefinitely extended, and in some individuals may be lifelong. Nevertheless, it is always relative. Whenever there is danger of exposure to a virulent strain of *variola major* the procedure should be repeated upon all persons who have not been successfully vaccinated or revaccinated within one year.

In the U. S. Army, vaccination at three-year intervals, and within one year prior to departure for overseas areas, has been found to be the most satisfactory routine from an administrative viewpoint. With this provision a few sporadic cases occur each year but all danger of epidemics is obviated. The intervals between vaccinations may safely be lengthened as a person grows older. The way to determine the immunity status of an individual is by observing the character of the reaction after vaccination with vaccine known to be of full potency.

Persons who have had smallpox may, after the lapse of time, exhibit a primary reaction to vaccine virus. This is not strange since second attacks of smallpox may occur in the same individual. On the other hand, there is some evidence to indicate that after vaccination the resistance to smallpox may last longer than does the immunity to revaccination. Likewise, the existence and size of an old vaccination scar bear no direct relation to immunity.

It is a fallacy to state that if repeated attempts to vaccinate an individual fail the subject is immune. A person may be unsuccessfully vaccinated many times before a typical take is obtained. No instance of natural immunity to cowpox has been conclusively demonstrated. Practically everyone is susceptible and the reactions are constant. Even heated (killed) virus will produce an immediate reaction (allergic) in an individual who is immune. The most common cause of failure is impotent virus. Calf lymph deteriorates rapidly unless it is kept extremely cold (see page 21).

The sera of human beings and of monkeys convalescent from vaccination possess neutralizing precipitin and complement-fixing antibodies. Moreover, it has been shown that such sera will agglutinate suspensions of elementary bodies. Interesting and illuminating studies of the nature of these immunity reactions and of the anti-

genic constitution of vaccine virus have been made by Craigie and Wishart, Smadel and Rivers and by others (Smadel, 1948).

**Contraindications.** Patients with generalized eczema and with diabetes should not be subjected to the risk of primary vaccination. On the other hand, if a child is fortunate enough to have had his primary vaccination in infancy, the presence of diabetes or eczema is all the more reason for maintaining immunity by revaccination at intervals of three to five years. Vaccination of an infant in poor nutritional condition or with congenital syphilis should be deferred until the child is in good condition, unless there is an immediate risk of exposure to smallpox. In community protection it is reasonable practice to omit vaccinating the enfeebled, the very sick, and those with infected skin lesions unless they are in danger. Pregnancy is not a contraindication. During the smallpox epidemic in Detroit, 1924, all patients were vaccinated on admission to the Herman Kieffer Hospital, which is the contagious disease hospital operated by the Detroit Department of Health. In all, 3,346 persons were vaccinated, including 773 obstetrical cases and 676 newborn babies, 90 cases of erysipelas, 425 cases of diphtheria, 644 cases of scarlet fever, 368 cases of tuberculosis, and others with measles, mumps, and other diseases. The takes were typical and there were no untoward results. Denny and Hopkins showed that when lepers are vaccinated the reaction is more pronounced than in normal individuals. At the same time, there is a flare-up of the specific lesions of leprosy, which, however, were in no case permanently aggravated; in fact, some showed actual improvement.

**Dangers and Complications.** In the United States the danger from vaccination has been grossly magnified. No figures on the subject are reliable before 1902, when the government passed a law setting up standards of purity and potency of vaccine virus and other biologic products. With proper precautions, the individual risk is now nil.

Vaccination must be looked upon as the production of an acute infectious disease which, although benign, should not be treated as trifling. The danger lies in the fact that we have produced an open wound, which is subject to the complications of any wound. Even a pin prick or a razor scratch may result in death. Before the days of asepsis, bacterial complications of vaccination were a matter of concern. When trouble ensues now, it is in instances where the vaccination was done by scarification or by large insertion, or where the site has not been kept dry, cool, and clean. Shields and other dressings have been the cause of complications; and in some instances infection has been scratched or rubbed into the take. It is now rare to see complications of any sort. In any properly vaccinated case, *the danger is infinitesimal when compared with the benefit conferred.*

Syphilis was formerly a complication in arm-to-arm vaccination, but cannot be transmitted with bovine virus. Tuberculosis and leprosy were formerly thought of as possibilities when human virus was used, but these also are eliminated by the use of bovine virus.

**FOOT AND MOUTH DISEASE.** This has in one instance been demonstrated as a contamination of vaccine virus. It is, however, impossible to convey foot and mouth disease to man through cutaneous inoculation. While no harm has been done to man, the contamination is undesirable and vaccine virus is tested to assure its freedom from this infection.

**AUTOVACCINATION.** Autovaccination is usually due to scratching the virus with the finger into the nose, the mouth, the mucous membranes or any part of the skin.



When carried into the eye it may cause blindness. In vaccine establishments accidental vaccination of the hand is common.

**GENERALIZED VACCINIA.** This is sometimes reported, but may be a mistaken diagnosis. The eruption of vaccinia is nearly always localized about the site of insertion. Satellite vesicles sometimes develop in the immediate neighborhood owing to the spread of the virus into minute nicks in the epithelium. With certain highly specialized strains of virus, generalized vaccinia in rabbits regularly occurs.

**TETANUS.** In view of the tremendous number of individuals vaccinated each year, many without benefit of surgical cleanliness, it is not surprising that tetanus has been reported as a complication, but an extremely rare one. Acland is acquainted with only one instance in more than five million vaccinations in England. Between 1904 and 1914, 41 cases of postvaccinal tetanus were authenticated in the United States. During this same period over 31 million doses of vaccine were distributed by manufacturers of biologic products. Investigations by the officers of the U. S. Public Health Service made since that time have clearly indicated the cause of this complication.

With the exception of an outbreak of postvaccinal tetanus in 1917, traced by McCoy and Bengtson to the use of bone point scarifiers, and of 17 cases traced by Armstrong to the use of infected bunion pads as protective dressings, the sources of the invading organism are unknown. Prolonged search by many workers, using a variety of methods, has failed to demonstrate *B. tetani* in commercial vaccine virus or in other vaccination materials procured from distributors. In 116 cases of tetanus following vaccination investigated by Armstrong (1929a) all developed after primary takes, which had been covered for all or part of their active course by some type of dressing strapped to the vaccination site. The kind of dressings employed were as follows: celluloid shields, 53; gauze, 40; bunion pads, 17; gauze and shield, 5; adhesive bandage, 1. The onset of symptoms of tetanus was found to be usually about 21 days after the vaccination had been performed; or about 10 to 12 days (the usual period of incubation in surgical wounds) after the lesion had reached its maximum reaction. From this and from experimental data, it appeared that the accumulation of broken-down material retained by the dressing at the vaccination site afforded conditions favorable to the growth of tetanus bacilli, accidentally introduced from extraneous sources. Accordingly, Armstrong advised that if a small superficial implantation of the virus be made by the multiple pressure technic, and no protective dressing be fixed to the vaccination site, tetanus would be eliminated as a complication. This advice has been proved correct by the experience of many years in the United States. Not a single case of tetanus has been known to have occurred where these precautions were observed.

**POSTVACCINAL ENCEPHALITIS.** This complication came to notice in 1922 when 11 cases developed in London. Up to 1929, England had reported nearly 100 cases, Holland almost 150 cases, and Germany 34 cases. Sporadic instances have occurred elsewhere. In Germany, there had been one case to approximately every 700,000 vaccinations; in England one to 48,000; and in Holland one to 4,000 (Armstrong, 1929b). In the United States we have a record of 38 probable cases during seven years, 10 of which occurred in 1927 and 13 in 1930.

The anomalous geographic distribution has not been explained. Even in Holland

same localities have an unusual prevalence, others have been spared. It has not been associated with any particular strain of virus.

The period of incubation is constant—10 to 12 days after vaccination. The extremes in the Holland cases were 5 to 20 days. Most of the cases occur between the ages of 6 and 16 years.

The symptoms in postvaccinal encephalitis are headache, vomiting, drowsiness, even coma; rigidity of the neck and Kernig's sign. The spinal fluid is under increased pressure, with a high cell count and sugar content. The case fatality rate is about 33 per cent, death usually occurring about a week after onset. The pathology is similar to that found in demyelinating encephalitis due to other infections, as smallpox, chickenpox, pertussis, measles, and mumps.

The cause of postvaccinal encephalitis is not known. Many students of the disease believe it to be the activation of a latent virus, in the same sense that herpes comes out in pneumonia and common colds. Others consider that it is part of vaccinia, much as nephritis complicates scarlet fever. Vaccine virus has been demonstrated in the spinal fluid of several children with postvaccinal encephalitis, but then the virus occurs there normally as part of a generalization following a take.

The prevention of postvaccinal encephalitis consists in suitable vaccination technique, with a superficial insertion, and no routine dressing. Infancy is the best time to vaccinate so far as this and other complications are concerned. Postvaccinal encephalitis has been observed only in primary vaccination; it has not occurred on revaccination.

**Compulsory Vaccination.** Vaccination affords a high degree of immunity to the individual and a well-nigh perfect protection to the community. To remain unvaccinated is selfish in that by so doing a person steals a certain measure of protection from the community on account of the barrier of vaccinated persons around him.

The laws and regulations (Fowler, 1927) concerning vaccination in the United States show a marked lack of uniformity. Massachusetts,\* Rhode Island, and New Hampshire stand with Hawaii, Puerto Rico, and Guam in requiring the vaccination of public school children. There has been a tendency to relax vaccination laws in a number of states. Utah even went so far as specifically to forbid compulsory vaccination as a prerequisite to school attendance. In England the conscience clause allows many persons to remain unvaccinated.

Decisions in the various courts in the United States have held compulsory vaccination to be legal. A decision of the Supreme Court of the United States (Henning Jacobson v. The Commonwealth of Massachusetts, April 1, 1905) upheld in every respect the statute, the validity of which was questioned under the Constitution:

"The liberty secured by the Constitution of the United States . . . does not impart an absolute right in each person to be, at all times and in all circumstances, wholly freed from restraint. Real liberty for all could not exist under the operation of a principle which recognizes the right of each individual person to use his own, whether in respect to his person or his property, regardless of the injury that may be done to others."

Theoretically, it would be ideal if all persons submitted to vaccination and revaccination voluntarily. But experience has shown that this is impractical, and, wherever tried, has failed. The best results have always been obtained where vac-

\* Massachusetts in 1809 was the first state to enact legislation relative to vaccination.



nation has been required, and this is the only present means by which smallpox may be eliminated.

*Vaccination certificates* should show the name and age; the date of application of the vaccine virus; the nature of the take, whether primary, accelerated or immediate; and the signature of a licensed physician. The data should be based upon observation of the course of the take. Accelerated and immediate reactions are to be interpreted as successful takes.

### VARIOLA INOCULATA

(Variolation) \*

The earlier practice of *inoculation* or *variolation* must be carefully distinguished from that of vaccination. By inoculation we mean the introduction of *smallpox* virus into the skin of man. The disease thus produced is usually mild, but nevertheless is smallpox, and just as contagious as smallpox; moreover, exposure may result in true, virulent smallpox.

Inoculation is a very old custom. It was practiced by the Chinese from time immemorial. The method was introduced into western civilization through Lady Mary Wortley Montagu, who learned of the practice at Constantinople and had her own boy "engrafted" with successful result. In 1717, Lady Montagu wrote her now famous letter to her friend Sarah Chiswell, and inoculation soon became popular in England, 1721, and spread to America and the Continent.† It was introduced into this country by Zabdiel Boylston at Boston. But the disadvantages were early realized and inoculation was soon replaced by vaccination. According to Plehn, inoculation is still practiced in central Africa.

The method of inoculation is similar to that of vaccination. The matter is obtained from the vesicle or pustule of a case of smallpox. This material is then introduced into the skin by means of a puncture, an incision, or through an abraded surface.

Following the inoculation of smallpox virus a local eruption appears on the fourth day at the site of the inoculation. This local eruption resembles vaccinia but develops more rapidly. Constitutional symptoms appear on the evening of the seventh or the morning of the eighth day following the inoculation. These symptoms resemble the onset of true smallpox and are rigor, headache, vomiting, and fever. The local eruption subsides on the appearance of the febrile symptoms but at the same time the general eruption breaks out. The crop is usually discrete, moderate in number, but runs the usual course through papule, vesicle, and pustule formation.

This phase of the subject may be made clearer by considering smallpox as existing in three forms (1) *variola vera* or true smallpox; (2) *variola inoculata* or

\* Variolation with smallpox was also called "suttonian inoculation" to distinguish it from its rival and ultimate successor, jennerian vaccination. *The Inoculator or Suttonian System of Inoculation*, by Daniel Sutton, London, 1796. J. N. Force, Univ. of Calif. Pub. in Pub. Health, 1931, 1: No. 7.

Fowlpox seems to belong to the smallpox family. The virus of fowlpox inoculated into the skin of the leg produces a modified, mild infection which protects. This method is in use on chicken farms.

† The practice of inoculation had been published in England as early as 1714 by Timoni of Constantinople, at Venice in 1715 by Pylarini, and in the same year in London by Kennedy, a surgeon who had been in Turkey. Its adoption and subsequent diffusion, however, were due to Lady Mary Wortley Montagu.

inoculated smallpox; (3) *vaccinia*, cowpox, or modified smallpox. The differences are shown in the following table.

<i>Variola Vera</i>	<i>Variola Inoculata</i>	<i>Vaccinia</i> or Cowpox
True smallpox Occurs only in man	Inoculated smallpox Occurs in man and monkeys	A derivative of smallpox Man, monkeys, cattle, guinea pigs, rabbits, rats, camels, and many other mammals
High mortality—25 per cent in some epidemics A general eruption, often confluent or hemorrhagic	Milder; rarely fatal; about 1 in 500 A local and a general eruption, fewer pustules (rarely over 200); seldom confluent or hemorrhagic	Benign; never fatal Always local and confined to the site of the vaccination
Highly contagious	<i>Equally highly contagious</i>	Not contagious — contracted only by mechanical transfer of vaccine virus
Period of incubation twelve days	Eight days' incubation	Three days' incubation

Emphasis must be placed on the fact that *variola inoculata*, while usually a mild disease, is just as communicable as true smallpox, and those who contract the disease in this way get true smallpox, sometimes in serious or fatal form. *Inoculation, therefore, protects the individual but endangers the community.*

Inoculation has fallen into disuse only because we have vaccination. There are conceivable emergencies in which the practice would be justified, for example, on board ship or on an island or in an out of the way place, in the absence of vaccine virus. Under such circumstances it would be essential to inoculate everybody at the same time.

The inoculation of smallpox will always remain for the student of hygiene one of the most interesting episodes in the development of preventive medicine. It illustrates in the clearest manner some of the fundamental phenomena of infection, susceptibility, and immunity. It was animal experimentation on a huge scale, the like of which we shall never see repeated on man as the subject. It is now a matter of regret that for the sake of science better advantage was not taken of the data.

### VACCINE

*Vaccinia*, or cowpox, is an acute specific disease, which runs practically the same clinical course in all susceptible species. The virus is widely distributed in the body. The eruption is local and confined to the site of the vaccinated area; the constitutional symptoms are mild. *Vaccinia* or cowpox is a benign disease; when uncomplicated, it has never been known to cause death or leave any unpleasant sequelae.

**Is Cowpox Modified Smallpox?** The unity or duality of these two diseases has been the subject of much contention. Jenner considered cowpox to be modified smallpox. The successful experiments in Germany, England, and this country, in which smallpox has actually been modified by passing variolous matter through calves, has demonstrated that we are dealing with two forms of one disease. When smallpox is thus converted into cowpox, it remains fixed as such and never reverts



to smallpox. Twenty-nine separate records of successful modification of smallpox virus into cowpox are found in the literature; also a number of negative attempts. Some of the strains obtained in this way have been used to vaccinate with typical takes and adequate protection.

Immunity to the acute communicable infections as a general rule is specific; in fact, it is a general principle in immunology that acquired immunity is usually exquisitely specific. This lends countenance to the assumption that cowpox is a derivative of smallpox.

**Spontaneous or Casual Cowpox.** The disease is said to occur "spontaneously" when its origin cannot be traced. It seems likely that so-called casual cowpox had its origin from smallpox through accidental inoculation in milking cows by persons having or recovering from smallpox. Once started, the propagation of the modified virus from cow to cow would be comparatively simple. It is highly significant that casual cowpox was much more common when smallpox was much more prevalent. In 1866 an instance of casual cowpox was discovered in Beaugency, France, and this virus, known as the Beaugency strain, has since been widely used.

**Strains.** Some strains of virus are more active than others. The original dermal strain has been adapted to other epidermal tissues, so that we have neurotropic and testicular strains.

*Vaccine virus* is the living specific principle in the matter obtained from the skin eruption of animals having "vaccinia" or "cowpox." Vaccine virus ordinarily is obtained from calves, but may also be obtained from older cattle, from man, rabbits, buffalo, caribou, camels, and other mammals.

*Seed virus* may be obtained (1) from casual cowpox, (2) from smallpox modified by passage through calves and (3) by retrovaccination. Each produces typical takes and adequate protection.

*Human virus* is no longer used on account of the risk of transmitting syphilis and perhaps other diseases peculiar to man. Another disadvantage is that it is not practicable to obtain the great quantities needed, especially at the time of an epidemic demand.

*Bovine virus* has been used since the time of Jenner, but especially since 1891 when Copeman showed the possibility of purifying it. Bovine virus has the great advantage of being readily obtainable in any amount and when desired. It may be purified with glycerin and phenol, and it further totally eliminates the danger of conveying syphilis and other diseases peculiar to man.

**Retrovaccination.** When vaccine virus is passed from calf to calf through a long series of transfers, it has a tendency to lose virulence and to give weak takes or failures. Serial propagation from animal to animal of the same species also tends to establish strains of associated skin bacteria with the virus. These bacteria may be repressed and even eliminated and the virulence of the vaccine virus restored simply by changing species from time to time. This is known as retrovaccination and is usually carried on by transferring the virus from calf to rabbit to calf; or, the virus may be passed from man through rabbit, monkey, or other susceptible animal back to the calf.



## PRODUCTION OF VACCINE VIRUS

**Propagation.** In the propagation of vaccine virus calves are preferred, because they are more manageable, the skin is more tender, and the eruption is, therefore, more abundant and typical. With young animals a milk diet may be used, which simplifies the problem of dust contamination from dry feed. If hay or fodder is used, it should first be autoclaved. Either heifers or bull calves are suitable, although the former are preferred.

The animals are held in quarantine for seven days under observation, to determine the absence of infections such as tuberculosis, glanders, foot and mouth disease, tetanus, fever, diarrhea or skin eruptions of any kind.

Before vaccinating, the calf is carefully cleaned and the site of the vaccination is shaved and prepared surgically, but without the use of strong germicidal solutions, for the reason that they may destroy the activity of the vaccine virus. Cleanliness and asepsis are the watchwords. The area selected is usually the abdominal wall between the tip of the sternum and the groin, sometimes including the inner side of the thigh. The usual method is to make long, superficial incisions in the skin about one centimeter apart, and the seed virus is gently rubbed into these incisions. The calves must then be kept rigidly isolated in a special room, moderately lighted, free from dust, and screened to keep out insects. The temperature of the animal is taken several times daily and the eruption at each stage of the disease is closely watched and recorded.

The virus is usually taken from the animal about the fifth day. It is an advantage to do so this early in order to avoid contaminating infections which may occur when the vesicles mature. Jenner's golden rule was to take the virus before the areola appeared; that is, before the seventh day. Virus taken after the eighth day is apt to produce unduly inflamed or abortive vesicles, called spurious takes by the early vaccinators.

The vaccination site is scrupulously cleaned by repeated washing and scrubbing and the pulp is then removed with a sharp spoon curet. Only typical and entirely characteristic vesicles are removed. Before the virus is taken, the animal is chloroformed or killed to avoid pain, and an autopsy is done after the virus is harvested. If the autopsy shows any lesions indicating infections other than vaccinia, the virus is discarded.

**Purifying or Ripening of Vaccine Virus.** Vaccine virus obtained from the skin always contains bacteria. The initial contamination may be lessened by care in propagation and harvesting of the virus. After collection, the virus may be treated to reduce greatly the number of bacteria which it contains. In the United States, vaccine virus is required to have fewer than 50 bacteria per dose and these must be nonpathogenic as determined by tests.

In 1891, Monckton Copeman made the important discovery of the selective action of glycerin for purifying vaccine virus.\* The glycerin acts as a differential germicide; that is, it is comparatively harmless to the virus but destroys the frail, nonspore-bearing bacteria. In time the virus itself succumbs.

\* Glycerin also serves as a preservative for other filtrable viruses, as foot and mouth disease, infantile paralysis, rabies, etc.

In practice, 2 to 4 parts of 50 per cent glycerin are added to 1 part of the pulp by weight. The amount of glycerin added depends upon the consistency and character of the pulp. The pulp should be thoroughly broken up and a uniform suspension obtained. The time required for the virus to lose most of its bactericidal effect depends upon the temperature. Most of the nonspore-bearing bacteria perish in 30 days at 15° to 20° C. Approximately the same effect may be obtained at 37° C in a few hours. At low temperatures the glycerin has practically no bactericidal effect. The process must always be controlled bacteriologically.

Phenol is commonly added to the pulp in 0.5 per cent concentration, to reinforce the bactericidal action of the glycerin. Both phenol and glycerin are selective germicides.

Because these agents exert a gradual destructive effect on the virus itself, old glycerinated virus is apt to be inert. Manufacturers in the United States date their products as potent for not more than three months "if kept below 5° C."

**Fresh Virus and Dried Virus.** Vaccine matter when dried remains potent for a long time, especially when dried, frozen and protected from oxygen and light. Formerly, physicians preserved the dried crust from a typical take. The old-fashioned dry points were prepared by drying vaccine lymph on splinters of ivory, and later on bone or glass. Dried virus still has a limited application in tropical countries because of its greater resistance to destruction by heat. Glycerinated virus should, however, be used wherever practicable.

**Government Control of Vaccine Virus.** By the law of July 1, 1902, vaccine virus sold in interstate traffic in the United States must come from a licensed manufacturer. These licenses are granted for one year by the U. S. Public Health Service after a careful inspection of the plant, personnel, and product, and are reissued only after reinspection. Each lot of vaccine virus must be examined carefully by modern bacteriological methods to determine the number of bacteria; tests including animal inoculations as well as cultural methods must be made to rule out pathogenic microorganisms. The government does not guarantee the purity and potency of each package of vaccine virus, but through its inspections and frequent examinations of the virus on the market every confidence may be had in the vaccine virus distributed by licensed manufacturers in this country.

**Care of Vaccine Virus.** Vaccine virus should always be kept ice cold until used. The warmth of the doctor's pocket, the office desk or the druggist's shelf may be enough to impair seriously its potency in a few hours. The heat of the railroad car or post office may soon render it impotent. This explains the difficulty sometimes encountered in obtaining potent virus during the summer months. Ice-box storage may not be enough. The packages of virus should be kept in small glass or metal containers in actual contact with ice. In an electric refrigerator packages of vaccine should be kept in an ice-making compartment. The ideal is that vaccine shall not be more than 30 minutes out of cold storage (below freezing) and that during the interval from removal up to the moment of use it shall be kept in a bowl of ice. Smallpox vaccine which has been out of cold storage so that it gives only about 80 or 90 per cent of successful vaccinations on previously unvaccinated individuals is not satisfactory and may be dangerously weak in the presence of severe smallpox.

Freezing does not injure vaccine virus; in fact, virus kept below freezing may



preserve its potency for years. Recent virus keeps better and gives more vigorous takes than old material. It is always advisable to keep a record of the name of the manufacturer and the lot number and expiration date found on the package. The handling of the container and capillary tubes should be governed by the principles of rigid asepsis.

**Egg Culture Virus.** Following the pioneer work of Goodpasture and his co-workers in 1935, a number of workers have shown that vaccinia virus will proliferate when inoculated onto the chorio-allantois of the fertile hen's egg. The possibility of using this method of production for vaccine was immediately realized. Certain advantages were obvious. Such a vaccine can be obtained completely free from bacterial contamination; it is relatively simple to prepare; it is cheap and obviates the necessity of using calves; if at any time there is an extraordinary demand for vaccine, this can be quickly met by inoculating a sufficient number of eggs. Preliminary studies by Goodpasture and his collaborators, and others, of the use of this material on animals and human beings indicate that its antigenic powers are similar to those of calf virus. The proportion of successful takes is comparable and the character of the reaction somewhat milder. The durability of the immunity and the protection afforded against natural exposure to smallpox, of virulent and mild types, has not yet been established by human trial.

There is some question as to whether a passage strain of vaccine virus cultivated on egg membrane remains stable in its properties, that is, whether its virulence may not suddenly increase or decrease. Until technical problems have been satisfactorily solved, the method remains in the experimental stage.

**Tissue Culture Virus.** Rivers and others (1939), and a number of other investigators have explored the use of preparations of tissue culture virus for human vaccination. It has advantages of the same order as those mentioned for egg culture virus; it also presents problems of the same nature. Preliminary trials are encouraging, but the method must still be regarded as experimental. Since the material is sterile it can be diluted and injected intradermally in precise quantities with a tuberculin syringe. Primary takes are milder than those with calf vaccine, and it is possible that the method may find a particular field of usefulness in giving a primary antigenic stimulus to infants with the least amount of disturbance.

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## CHICKENPOX

(*Varicella*)

Although characteristic features of chickenpox were described as early as 1767 by Heberden, it is not surprising that it was confused with smallpox until the nineteenth century. At times even today these two diseases are differentiated with considerable difficulty.

The usual incubation period of chickenpox is 13 to 17 days, the maximum for isolation purposes being 21 days. The prodromal period is short. The onset is sudden with some elevation of the temperature and mild constitutional symptoms. Within 24 to 48 hours the eruption makes its appearance. In the milder cases it may be the first symptom noted. In contrast with the smallpox eruption which comes out as a single crop, in chickenpox there is a succession of crops, new lesions continuing to appear for three to four days even upon the same part of the body. For this reason they may be seen in all stages of evolution at the same time. Some lesions do not go beyond the papular stage, but most of them become vesicular. In general, the vesicle is more superficial. The surrounding areola and indurated base is smaller and less marked than in smallpox. While in chickenpox the vesicles tend to be more abundant on the covered portions of the body, in smallpox the reverse is true. For this reason indurated papules are found less frequently in the palms of the hands and on the soles of the feet than in the latter. The vesicles dry; crusts and scabs are

formed which fall off in 5 to 20 days depending upon the depth to which the skin has been involved.

As with *variola minor* the case fatality rate is extremely low. Probably no one ever dies of chickenpox per se. Complications are infrequent, but in debilitated persons, adults, and infants may cause death. The case fatality rate for all ages rarely exceeds 0.4 per cent. In severe cases with recovery a few scars and pockmarks may remain.

While in typical cases chickenpox and smallpox can be differentiated on the basis of clinical evidence alone, instances occur in which this is insufficient. This may be the cause of considerable embarrassment to the practicing physician and the health officer, and is a matter of considerable importance to the community. From the point of view of civic safety, where there is reasonable clinical doubt, the suspicion of smallpox should be entertained until this possibility can be dismissed. Further evidence is sought along three lines—the previous history of the patient, the source of the infection, laboratory procedures and, upon occasion, the result of a vaccination done after convalescence.

The history of the patient should receive consideration with reference to previous attack from smallpox or chickenpox or both, bearing in mind the possibility of a second attack of either. Of similar importance is the vaccination history; the existence of a vaccination scar must be interpreted with reference to time. Though smallpox is more frequent in the unvaccinated, neither the vaccination history nor the presence of scars should be given much diagnostic weight.

Inquiry into the source of the infection will usually reveal the clinical characteristics of the case or cases from whom the patient was infected. Where doubt remains during convalescence, it may be removed by the manifestations of disease in the exposed contacts. A successful take, primary reaction, obtained with vaccination after recovery is reasonable proof that the suspected illness was not smallpox; on the other hand, a vaccinoid or immediate reaction does not prove that it was, even though the history of previous attack and of previous vaccination be negative. Occasionally, diagnostic laboratory tests are resorted to in order to establish whether or not the virus is that of smallpox (see page 5).

**Chickenpox Virus.** The causative agent of chickenpox is a virus similar to that which causes smallpox but is immunologically distinct. Characteristic elementary and inclusion bodies have been described. It is closely related to the virus which causes herpes zoster (shingles), but evidence that they are identical is not conclusive.

Experimental animals so far tested are refractory with the possible exception of young vervets and green monkeys (Rivers, 1926). Little is known as to its resistance to external conditions and to physical and chemical agents. It seems reasonable to suppose that it is not essentially different from vaccinia in these respects.

**Host Relationship.** So far as is known man is universally susceptible to this infection. It is thought that the virus enters through the respiratory tract and is distributed by way of the blood stream to the cutaneous tissues and mucous membranes. Here it proliferates and can be demonstrated in fluid from the vesicles.

Epidemiological evidence indicates that the patient ill with this disease is infectious for contacts from about 24 hours before until about 6 days after the appearance



of the eruption. The crusts and scabs persist for a much longer period but do not appear to be the source of contact infections (Gordon and Meader, 1929).

The virus makes effective exit from the human body principally, if not solely, in secretions from the upper respiratory tract, perhaps as a result of the breakdown of mucous membrane lesions which occur early in the course of the disease. Transmission to a new host is effected by air-borne droplets and droplet nuclei, and perhaps less frequently by contaminated articles. It is one of the most readily communicable of diseases.

In the United States about 70 per cent of persons who have reached adolescence give a history of having had a clinical attack. Mild attacks with very little if any constitutional disturbance and a few lesions scattered over the body commonly escape recognition. The existence of true subclinical infections or of healthy carriers has not been proved. A single attack confers a durable immunity.

Man is the reservoir host of the virus and it maintains itself in human populations by case-to-contact transfer. In all large communities it is constantly endemic, although the incidence rises during the winter and spring months. The smaller and more isolated communities may escape for periods of time. When the infection is introduced by an imported case, the rapidity and extent of spread is determined largely by the immunity status of the exposed population.

**Prevention.** Recognized cases should be isolated. Exclusion from school is generally required. Restrictions upon the patient can be terminated safely at the end of seven days, even though a few crusts and scabs may still be present on the skin. Public opinion may demand isolation until all crusts and scabs have disappeared. Susceptible contacts may be permitted to continue normal activities until 12 days from the earliest exposure date; during the succeeding week they should be carefully observed and excluded from school upon appearance of symptoms.

Because of the high degree of communicability, the frequent occurrence of mild missed cases, and because the patient is infectious for 24 to 48 hours before diagnosis is established, community spread can be retarded or reduced by isolation procedures, but only occasionally prevented.

Vaccination with chickenpox virus has been proposed, but for many reasons it is not practical at present.

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#### MEASLES

(*Morbilli, Rubeola*)

Morbilli is the diminutive of morbus, little disease, in contrast with smallpox. Rubeola is derived from the Arabic meaning red spots. Rhazes of Bagdad, about 900 A.D., clinically differentiated between measles and smallpox. The credit for separating measles from scarlet fever is given to Sydenham whose works were published around 1675, but he did not distinguish between measles and smallpox. The latter differentiation was reasserted in English medicine by Withering in 1792,



Recognition of German measles (Rubella) as a distinct entity dates from the early nineteenth century.

**Clinical Manifestations.** Measles is the most widely distributed and most commonly recognized of all of the eruptive fevers to which man is subject. It is also the most constant in its primary clinical manifestations. Mild abortive cases which cannot be clinically identified are relatively rare. Inapparent infections and convalescent carriers are not known to occur. The incubation period is commonly 10 days from exposure to appearance of recognizable symptoms, about 12 to 14 days from exposure to appearance of rash (Sartwell, 1950).

The onset of the disease is marked by the appearance of fever and malaise followed promptly by catarrhal symptoms which increase up to the development of the eruption. The characteristic symptoms of the pre-eruptive stage are those of severe coryza—suffusion of the eyes, increased lacrimation, photophobia, sneezing, discharge from the nose—and cough. The first manifestations of the eruption usually become evident from two to six days after the onset. Before the cutaneous eruption the spots described by Koplik in 1896 appear upon the buccal and labial mucosa.\* The cutaneous erythematous, maculopapular measles eruption begins to effloresce and extends rapidly to the entire body. In an uncomplicated case the temperature returns to normal in three to five days. Within a day or two after the fever has ceased the rash has disappeared except for a pale residual pigmentation which may last for a few days longer. A fine branny desquamation follows.

Measles per se is seldom fatal, but the morbid process which it initiates upon the mucous membranes of the upper respiratory tract lowers resistance to invasion by potentially pathogenic micro-organisms already present or which are acquired during the course of the disease. Most common is an ascending infection involving the sinuses or the middle ear. The greatest danger arises from pulmonary complications which are responsible for nearly all fatalities.

If roentgenograms are made routinely, pneumonic infiltrations are found in about one fourth of the cases in the pre-eruptive stage and in approximately one half as the eruption subsides. The mediastinal lymph nodes are often considerably enlarged, even when pneumonia is absent; this enlargement may persist into convalescence. The early appearance of these lesions supports the view that they are initiated by the virus itself, a conception which also receives support from the studies of measles pathology. The initial process is a peribronchial pneumonitis, but it is rapidly obscured by the invasion of pyogenic micro-organisms, causing broncho-pneumonia. A small proportion of cases go on to the development of empyema, and chronic pneumonia with bronchiectasis.

**Frequency of Complications and Death.** As is seen in the accompanying tabulation, the death rate from measles, as from other common communicable diseases of childhood, has decreased remarkably during the past half century in the Death Registration Area of the United States. Most deaths occurred in children under

\* According to Koplik, they are described as "small, irregular spots of a bright red color. In the center of each red spot is seen a minute bluish white speck. There may at first be only two or three or six such, rose-red spots, with a bluish white speck in the center. The combination of a bluish-white speck with a rose red background on the buccal and labial mucous membrane is absolutely pathognomonic of the invasion of measles. Sometimes the bluish white speck is so small and delicately colored that only in a very direct and strong daylight is it possible to bring out the above effect, but the combination is always present."

Table 1-2. Death rates per 100,000 estimated midyear population for common infectious diseases of childhood

Cause of Death	Death Registration Area, United States						
	1910	1920	1930	1940	1945	1947	1950
Measles	12.3	8.8	3.2	0.5	0.2	0.3	0.3
Scarlet fever	11.6	4.6	1.9	0.5	0.2	0.1	0.0
Whooping cough	11.4	12.5	4.8	2.2	1.3	1.4	0.7
Diphtheria	21.4	15.3	4.9	1.1	1.2	0.6	0.3

Figures from U.S. Mortality Tables.

three years of age. Under ordinary conditions of prevalence in the civilian population, case fatality rate in children under one year of age is less than eight, during the second year less than four, during the third year less than two, and throughout the rest of childhood and adult life a fraction of 1 per cent. With the introduction and effective use of antibiotics for the treatment of complications, where good medical service is available, the risk of death has been reduced to a very low level indeed in all except very young infants.

Historically, there are on record widespread epidemics of measles in "virgin" populations accompanied by high mortality rates. These have occurred particularly among uncivilized people, living under very primitive conditions, in the absence of all rational treatment of the sick (Hirsh, 1883). A classical example is the epidemic of measles in the Fiji Islands in 1875 as reported by Squire. These islands had been free from the disease for many years. The native Chief, Thacombau, returning with his retinue from a visit to Sydney, Australia, introduced the infection. The disease spread rapidly throughout the islands. During the succeeding four months the estimated deaths were 20,000, or one fourth to one fifth of the native population. "Thousands were carried off for want of nourishment and care as well as by dysentery and congestion of the lungs; the worst dangers from overcrowding were incurred in the small houses and the worst danger from cold by the sufferers rushing into the water where they would continue immersed."

At times, measles has been a disastrous disease among military populations. An illustration is the U. S. Army experience in 1917-1918. In some of the camps which were filled with recruits from rural sections of the south there were sharp outbreaks of measles. Cases were hospitalized and there was a high incidence of secondary pneumonia. Among the 4,000,000 troops there were 96,817 admissions for measles; 2,367, or 2.4 per cent, of these terminated fatally. Dunham estimates that the case fatality rate for post-measles pneumonia was 35 per cent. On this basis there were some 6,700 cases which had this complication. In some camps the proportion of measles cases which developed secondary pneumonia was much higher than in others. Studies made by Army Commissions indicated that hemolytic streptococci and pneumococci were the most common secondary invaders (Opie and others, 1921). In the 1951 epidemic in South Greenland there was a morbidity rate of the order of 99.8 per cent, with 4,320 cases and 77 deaths.



In civil populations, Godfrey (1928) has called attention to the large proportion of the total measles deaths which occur in institutions caring for young children and the high case fatality rates which may prevail. In one group of these institutions, in which there were two epidemics during 1916 and 1918, the case fatality rate for all children was 24 per cent, for children under one year it was 45 per cent. These high rates were attributed to undernourishment, overcrowding and inadequate care during the epidemics. When practical methods were introduced to give better medical care, the case fatality rate for all ages was reduced to less than 2 per cent. From this experience it would seem that the case fatality rate is very largely determined by the character and adequacy of medical care.

Panum's *Classic Studies on Epidemic in the Faroe Islands*. Much that we know about measles was contributed in the admirable report of Panum (1847) who was sent to the Faroe Islands in 1846 as a member of a medical commission to study an outbreak of measles. Measles had disappeared from the Faroe Islands in 1781, so that they were free of the disease for a period of 65 years when the epidemic of 1846 occurred. It was brought into the Islands by a cabinet maker, who left Copenhagen March 20 and reached Thorshaven on March 28 in good health. A few days before leaving Copenhagen he had come in contact with a case of measles, and on the fourteenth day thereafter, some days after reaching Thorshaven, he developed the disease.

Panum demonstrated that the period of incubation of the disease is usually 13 or 14 days; that all ages are susceptible; that one attack produces a definite immunity; that the disease is most readily transmissible at the time of the development of the eruption, but that it may be transmitted during the prodromal period and before the appearance of the rash, but in no instance did he find that it was transmitted during the period of desquamation.

Out of 7,864 inhabitants of the Faroe Islands, about 6,100 had measles. There were 170 deaths—a case fatality rate of 2.8 per cent for all ages, but 28.6 per cent for infants under one year of age.

**Experimental Measles.** In the literature of the eighteenth and nineteenth centuries, beginning with the treatise of Home in 1759, there are to be found a number of accounts of human inoculations with blood and other materials taken from measles patients. Suggested by the procedures of inoculation or variolation as a prophylactic measure against smallpox, this so-called *morbillisation* was attempted with the object of inducing a mild disease which would lead to a permanent immunization of the subject. Hektoen (1905) critically reviewed these old reports. He concluded that, although it is exceedingly probable that measles was often produced as a result of inoculation, the possibility of intercurrent natural infection through contact a posteriori could be absolutely excluded.

Monkeys belonging to the several species of the genus *Macaca* have been shown to be susceptible (Shaffer and others, 1941), but are more resistant than human beings. When successfully inoculated they present a clinical symptomatology somewhat similar to that of a mild, abortive case in man. The virus can be recovered from the buccal mucosa of infected monkeys killed two to six days from onset, and from the blood during the first five days of the illness. Similarly, it is present in the blood and the nasal and buccal secretions of human patients 24 and often 48 hours before the appearance of the eruption, as has been shown by inoculation experi-



ments and by instances of accidental infection from transfusion. It persists in the blood and secretions for at least 24 hours after the appearance of the eruption, but cannot be recovered after the temperature curve has begun to subside. The desquamated skin is not infectious.

Many attempts have been made in recent years to grow the virus of measles in tissue culture. Some were unquestionably successful. Particularly notable is the demonstration of Rake and Shaffer (1940) that measles virus could be grown on the chorio-allantoic membrane of the developing chick embryo in successive passages. It was subsequently found that (Shaffer and others, 1941) virus from the early egg passages is capable of producing mild measles in the monkey and a slightly modified disease in man. Some of the monkeys developing typical measles from passage virus were subsequently resistant to challenge with active virus from human sources. Furthermore, it was demonstrated that passage virus could produce mild measles with typical Koplik spots in small groups of susceptible children. Later passages of the egg culture virus resulted in a greatly modified disease with slight symptoms or signs or nothing at all.

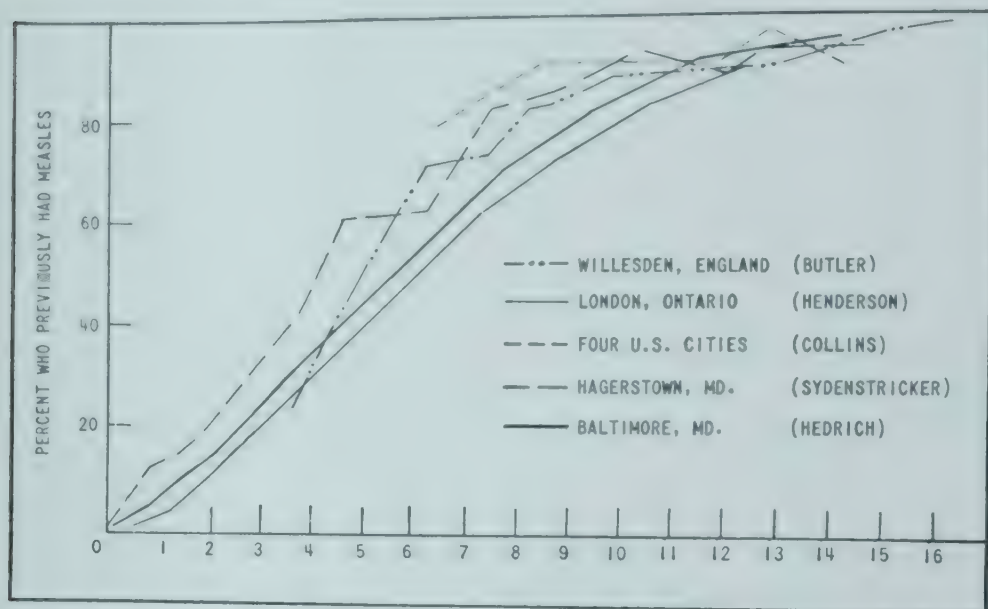
**Experimental Vaccination of Children with Measles Virus.** An extensive study of the usefulness of the vaccine produced by the growth of measles virus in the chorio-allantoic membrane of fertile hens' eggs was undertaken by Maris and others (1949). Their conclusions were that the chorio-allantoic membrane vaccine produced mild symptoms of measles in a large number but not in the majority of children vaccinated. Whatever protection was afforded by vaccination procedure was minimal in degree. The reasons for the failure of the vaccine to afford better protection are not evident.

**Transmission.** The virus is an obligate parasite of the upper respiratory tract of man. No other animal species is known to be naturally infected. Transmission to a susceptible person is effected directly by droplets or droplet nuclei expelled during talking, coughing, or sneezing. The virus may also be transmitted indirectly by articles freshly soiled with buccal or nasal discharges. The contagion can be indirectly conveyed by droplet nuclei in air currents for short distances and time periods in enclosed spaces. The virus dies within a few hours outside the body. Accordingly, transmission by infected droplet dust particles and contaminated articles becomes a relatively unimportant medium.

**Prevalence.** Measles is propagated in the human race by chain transmission from cases to susceptibles. Under modern conditions of living and transportation the disease is never long absent from any community. It is continuously propagated throughout the year and from year to year in all large cities.

An infant enjoys immunity from infection during the first few months of its life provided the mother has had the disease. Thus, in any community a susceptible population is constantly being recruited by maturing infants and by new arrivals who have not had the disease. Exposure to infection is inevitable. The rate at which measles is acquired in urban communities is indicated by the accompanying figure (Fig. 1-2). Approximately 95 per cent of the children at the age of 15 have previously had measles. Depending upon circumstances in a rural or isolated area exposure may be delayed and a greater proportion of individuals remain susceptible into adult life. A single attack confers a high and durable immunity. Although second attacks may occur they are extremely rare. Thus, Panum observed: "Of the

many aged people still living on the Faroes who had measles in 1781, 65 years previously, not one, as far as I could find out by careful inquiry, was attacked the second time. I myself saw 98 such old people who were exempt because they had had the disease in their youth. This was the more noteworthy in that a high age by no means lessened the susceptibility to measles, since, so far as I know, all the old



From Hedrich, A. W., *Am. J. Hyg.*, 17:619, 1933.

Fig. 1-2. Four observations of measles history by age; also, calculated rates for Baltimore.

people who had not gone through with measles in earlier life were attacked when they were exposed to infection."

This process of conversion of susceptibles into cases and cases into immunes goes on in all human communities intermittently or continuously. There are periods when transmission is going on at a rapid rate (epidemic prevalence) and periods when the disease is being propagated at a low level, smouldering in the population (endemic prevalence). In the smaller communities there are periods when the disease is absent. Over a half century ago it was realized that the principal factor which determined epidemic spread was the accumulation of susceptibles in the population (Hamer, 1906). When the proportion of susceptible persons reaches a level which is critical in relation to climatic and other external conditions in a community, the disease tends to spread widely. As cases are converted into immunes, the proportion of susceptibles falls. The accumulation of immunes acts as a damper upon further spread. The rise and fall of incidence is thus explained as due very largely to the balance between the proportion of susceptibles, cases and immunes in a population. It is further modified by climatic and other environmental conditions. The colder months of the year are more favorable to transmission than are the warmer months. Consequently, measles exhibits a more or less constant seasonal pattern. In all large population groups the prevalence reaches a maximum during the late winter or early spring months and minimum during late summer months. In addition to the regular seasonal increase and decrease there is an interannual



variation which is manifested by peaks or epidemics recurring at intervals of two, three or more years.

**Immune Globulin.** After an attack of measles the blood is rich in immune bodies able to neutralize the virus of measles. This property of the blood gradually weakens with the years but retains its efficacy for life. Convalescent serum obtained between the tenth and thirtieth days is most effective—from three to five times as protective as adult serum obtained many years after an attack of the disease. There is no accurate quantitative method of measuring the potency—the efficacy is determined by clinical results.

Five ml. of convalescent serum for a child and 10 ml. for an adult will usually protect against measles if given before the middle of the period of incubation, namely, the fifth day after exposure. The protection is passive and transient and cannot be depended on for more than about three weeks. If adult serum is used, 15 to 20 ml. will protect. Injections are given intramuscularly.

If given after the middle of the incubation period (between the fifth and eighth days) the serum will not prevent but is likely to modify the disease. This modification consists in a prolongation of the period of incubation (17 to 18 days) and amelioration of the severity of the attack. There is usually fever and some catarrhal symptoms, but the Koplik spots or the rash may be absent. Large doses of serum are required during the catarrhal stage to lighten the symptoms. After the rash appears, the serum has no apparent effect.

There is great advantage in giving the serum during the middle third of the period of incubation so as to produce a mild attack, for the reason that this is followed by a lasting active immunity. Whereas, if the serum be given during the first part of the incubation period and the disease prevented, the immunity is passive and transient. The only exception to this rule is in feeble or tuberculous children who should be spared measles, however mild.

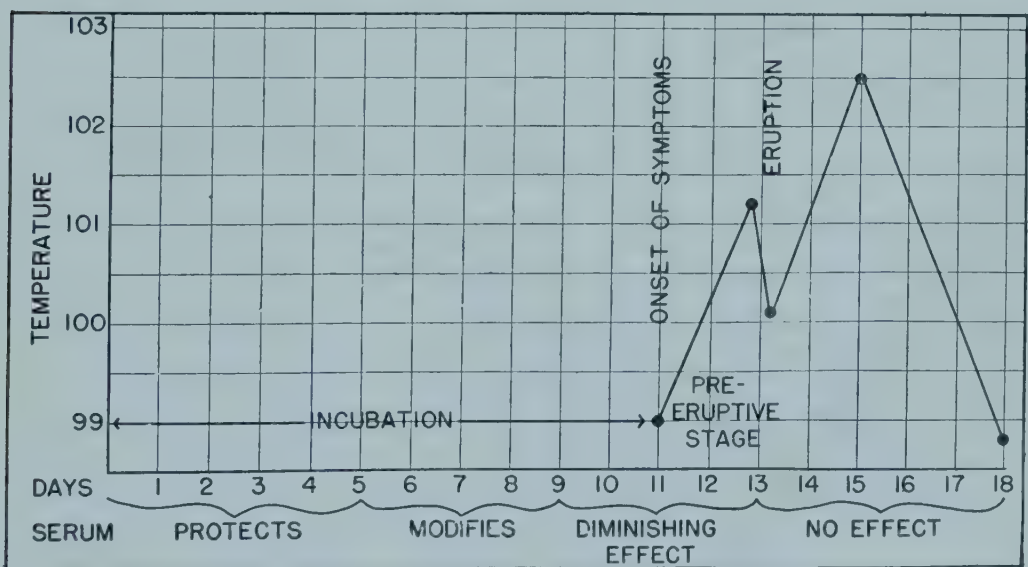


Fig. 1-3. Effect of measles convalescent serum with reference to time of administration; also, typical temperature curve of the disease.



Figure 1-3 shows graphically the effects to be expected with convalescent serum. The results are sometimes disappointing or different because of varying antibody content and time after exposure.

McKhann and his associates (1935) showed that serum contained in human placentas could be purified and concentrated to give an antibody concentrate (immune globulin) or placental extract which was as potent as the average convalescent serum. Apparently, because of the nature of the raw material and certain processing difficulties inherent in the method, local and systemic reactions have been noted following the use of placental extract and its usefulness has been correspondingly limited, moreover, it entails the risk of inciting serum hepatitis.

The development of a large scale blood procurement program during World War II and the correspondingly unprecedented quantities of human plasma which became available made possible a new approach to the provision of measles antibodies from normal adult human blood. A considerable proportion of the blood collected for military purposes was fractionated by Cohn and his associates (1944) to produce gamma globulin. It has been shown that gamma globulin (immune globulin human) contains measles antibody in a concentration about 25 times that found in the original plasma from which it was made (Enders, 1944).

Several studies have demonstrated the efficacy of gamma globulin or immune serum globulin in the control of measles. It is known to have a consistently higher and a more uniform potency and greater freedom from reactions than any other generally available form of measles antibody. By proper adjustment of the dose it is possible in most cases to select either modification or protection as the objective (Janeway, 1944). Modified measles is desirable for healthy children over three years of age, except in those unusual circumstances which justify complete protection. Modification can usually be obtained by the injection of .02 to .025 ml. of gamma globulin per pound of body weight, preferably within four or five days of known exposure to measles. If modification is obtained the incubation period is frequently prolonged to as much as 17 to 21 days, catarrhal symptoms are usually slight, temperature lower, Koplik spots may be absent, and the rash may be mild and transient. Complications are practically never seen. Modified measles is probably just as infectious as the unmodified form. Therefore, if a quarantine is to be imposed, it should be extended to three weeks after exposure. If the course of the disease is too greatly modified it is questionable whether the immunity conferred is sufficient to afford durable protection.

Complete protection of an exposed susceptible from measles may be obtained for perhaps three to four weeks by injection within six days after known exposure of .075 to 0.1 ml. of gamma globulin per pound of body weight. Such protection is justifiable in children under three but not in infants under four months, in children who are debilitated or otherwise ill, particularly with tuberculosis or rheumatic fever, in institutional groups, in pregnant women and in a few other special situations. The immediate apparent advantages of complete protection should always be weighed against the temporary nature of the protection obtained, which necessitates repetition of the dose at intervals of three to four weeks if exposure to measles continues to occur, against the fact that any blood product is now, and always will be, difficult to supply in quantities sufficient for those who really need it.

**Prevention.** There is no satisfactory evidence that in large communities the spread of measles can be materially reduced by isolation of patients and restrictions placed upon susceptible contacts. The principal reason is that it is contagious in the pre-eruptive, ambulatory stage before diagnosis is made. Moreover, since it is generally regarded as an unimportant disease of childhood, many cases are not brought to the attention of physicians. Exposure for every individual is inevitable. The only permanent protection is by the acquisition of immunity by having measles. In view of these considerations, preventive measures are directed principally toward reducing the frequency of complications and death.

The chief objectives are (1) to provide adequate medical care for every case of measles, (2) to protect so far as practicable the exposure of children under three years of age. Cases should have bedside care and, if possible, separate room isolation at home. Hospitalization is undesirable unless isolation facilities are adequate. Isolation not only tends to reduce spread to the remaining susceptible contacts but, equally important, serves to protect the patient from exposure to dangerous secondary infection during a period of lowered resistance of respiratory mucous membranes. Protective isolation of measles should be continued until convalescence is established. Services of a physician should be readily available to institute therapy with antibiotics in the event of complications. Ordinarily, in large communities, quarantine of exposed susceptible children is impractical. In sparsely settled rural communities some restrictions of susceptible household contacts may be justified. If the date of exposure can be reasonably established, an exposed susceptible may be allowed to attend school for the first seven days of the incubation period; otherwise, exclusion from school until 14 days from last exposure may be required.

During an epidemic it is not advisable to close schools and discontinue classes. Daily examination of the children by a physician or competent nurse should be provided. A nonimmune child presenting symptoms of coryza or cold or a temperature of  $99.5^{\circ}$  F should be placed under observation pending diagnosis. The principal justification for attempting to retard spread through a school population is to reduce the risk of carrying infection home to a family in which there is a child under three years of age.

Up to 92 per cent of the susceptible children exposed to intrafamilial contact may come down with the disease, depending upon their ages.

Immune globulin or immune serum should be made readily available. Its use should be restricted to children under three years of age, pregnant women, or children who are poor risks for any infectious disease because of poor health. In each case a physician should decide whether the objective of the prophylactic should be to modify the infection or to give complete protection. Services of visiting nurses should be made available, especially to the poorer families.

In a preventive program, institutions caring for infants and children should receive particular attention. Those responsible for the medical welfare of the inmates of such institutions should be fully acquainted with their responsibilities. Facilities adequate for the medical care of the maximum number of cases which might be expected in an outbreak should be made available in such manner as to avoid the hazards of crowding and cross infection. Provision for the segregation of infants is



Table 1-3. Measles attack rate among susceptible family contacts according to age

Age	Data of Fales (Baltimore)			Data of Top (Detroit)		
	Exposed Persons Without History of Previous Attack	Subsequent Cases in Family	Attack Rate Per 100 Susceptibles	Exposed Persons Without History of Previous Attack	Subsequent Cases in Family	Attack Rate Per 100 Susceptibles
Under 1 year	585	189	32.3	165	78	47.3
1 year	593	458	77.2	178	164	92.1
2 years	657	521	79.3	246	225	91.5
3 years	654	547	83.6	304	284	93.4
4 years	729	611	83.8	255	232	91.0
5 years	582	471	80.9	207	180	87.0
6 years	369	316	85.6	107	89	83.2
7 years	256	208	81.3	75	60	80.0
8 years	199	160	80.4	56	44	78.6
9 years	144	98	68.0	40	24	60.0
10 years	112	60	53.6			
11 years	85	44	51.8			
12 years	53	23	43.4			
13 years	58	15	25.6			
14 years	31	7	22.4			

From Holt and McIntosh, *Holt Pediatrics*, 17th ed., New York, Appaon-Century-Crofts, Inc., 1953.

particularly important. Immunization with immune globulin of all the younger children who have not had measles may be of value in reducing the rapidity of spread and avoiding overcrowding in wards or dormitories used for the care of the sick.

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GERMAN MEASLES

(*Rubella*)

German measles is an extremely mild eruptive fever which was separated as an entity distinct from scarlet fever and measles (rubeola) by Wagner, a German clinician, in 1829. Differentiation of these three diseases came slowly into practice; they are still confused at times. Rubella was considered unimportant until the brilliant observations of Gregg (1941) were made on the serious effects of the disease on the fetus in utero of pregnant females.

**Clinical Characteristics.** The incubation period is longer than in measles, 14 to 23 days, averaging about 18. Prodromal symptoms are slight and rarely last more than half a day; the rash may be the first symptom to attract attention. Swelling of the postauricular, suboccipital and cervical lymph nodes is one of the most constant features and an extremely useful one in establishing an early diagnosis. It may appear three to five days before the constitutional symptoms and eruption. In severe cases there may be a general lymphadenopathy, involving nodes in other parts of the body.

The character of the eruption varies somewhat but in most cases resembles that of measles more than that of any other disease. It spreads rapidly over the whole body and is composed of very small discrete maculopapules, pale red, and varying in size from a pin's head to a pea. Over the face they frequently become confluent. Sometimes there is a fairly uniform red blush over a large part of the body which bears a close resemblance to scarlet fever. About the time the eruption appears there may be a slight elevation of temperature—rarely exceeding 101.3° F. The course of the illness is a matter of one to three days; the lymph nodes may remain enlarged for some time afterward. Complications and sequelae are extremely rare.

**The Virus.** Hiro and Tasaka (1938) reported successful experimental transmission subcutaneously of the disease to children exposed to nasal washings filtered through a Berkefeld w. or Seitz, e.k. filters. Habel (1942) found *Macaca mulatta* monkeys to be susceptible to infection. He found virus in the blood up to 30 hours after the appearance of the rash. Filtered nasal washings were positive up to 24 hours. He isolated virus from one case without a rash. He was also successful in transmitting rubella to a monkey after five passages on the chorio-allantois of the chick embryo. He found no evidence of cross immunity with measles virus.

**Prevalence.** In its host relationships rubella resembles measles in that it is specifically dependent upon man for its survival. It is maintained in human populations by chain transmission from infected individuals to susceptibles. The infectious agent is contained in the nasopharyngeal secretions. The duration of the infectious period

has not been determined but Smith (1947) found it safe to allow children to return to school after four or five days from appearance of the rash. Susceptibility is general after the first few months of life until immunity is acquired. A considerable proportion of individuals become immune as a result of unrecognized or subclinical infection.

During epidemic prevalence many cases escape diagnosis and the disease receives little attention. It tends to prevail in widespread epidemics separated by longer intervals of time than in measles. Hence, it is more likely to have a somewhat older age distribution, although children are principally affected. The seasonal incidence of the disease is somewhat similar to that of measles.

**Relation to Congenital Defects.** The original observations on the relationship of rubella in the pregnant mother to the occurrence of congenital defects in the infant were made by Gregg and others in Australia (1945). His observations have since been confirmed and extended by many investigators. In the Australian studies it was found that of all the congenital defects, microcephaly (74 per cent) and deafness with secondary mutism (69 per cent) were the most frequent, cardiac malformations (39 per cent) and eye defects, particularly cataracts (17 per cent), following in that order. Later studies in the United States and in England have increased the number of specific defects which were attributed to this cause to include dental abnormalities, clubfoot, cleft palate, spina bifida, and others. There seems to be general agreement that infection of the mother is most dangerous in the first two months of pregnancy. The risk decreases when the infection occurs during the third month and after the fourth month there appears to be little danger. There is no relationship between the severity of the maternal infection and the nature of the defect. The Australian studies suggest that malformations and defects may occur in 90 per cent and more of infants (Swan and others, 1946); more recent American studies, made under somewhat different conditions (Ingalls and Gordon, 1947; Ober and others, 1947), estimate that they occur in about 50 per cent of infants born to mothers who have rubella in the first three months of pregnancy. So definitely has this relationship been established that it is considered to be an indication for therapeutic abortion. In assisting the pregnant woman to come to a decision regarding therapeutic abortion following rubella infection, the physician should bring to her attention the consideration that the chance of a congenitally abnormal child is substantial. A young woman or one with several other children may elect to terminate a particular pregnancy complicated with rubella. On the other hand, an older woman in her first pregnancy may wish to accept and continue to term.

**Control Measures.** There is no evidence that the spread of rubella in a community can be prevented by isolation of cases and restrictions made upon susceptible contacts. The disease is infectious before diagnosis can be made. There are a great many unrecognized and subclinical infections. It is so mild that a great proportion of cases never come to medical attention. Exposure is inevitable. The only protection is immunity acquired through attack. This immunity can be acquired without penalty, provided it does not occur in the female during the childbearing period. Control measures are accordingly concentrated upon protecting the pregnant female. It is desirable that every girl should have rubella before reaching the childbearing period. Expectant mothers should be informed concerning the danger if they have never had rubella or if the matter is in doubt because of faulty diagnosis and every



effort should be made to protect her from exposure to this disease if it is known to be occurring in the vicinity. If, despite precautions, she has a known exposure, prophylaxis with immune globulin as in measles should be attempted even though its value has not yet been definitely established. In the event that a woman develops rubella during the first four months of her pregnancy, the artificial termination of the pregnancy should be considered by the consulting obstetrician.

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#### MUMPS

##### (Epidemic Parotitis)

Mumps was one of the first common contagious diseases to be differentiated. It was described by Hippocrates as a mild epidemic sickness characterized by non-suppurative swellings near the ears and occasionally accompanied by enlargement of the testes. With recognition that it is primarily an involvement of the parotid glands, the disease has commonly been called epidemic parotitis.

**Clinical Manifestations.** The infectious process may affect not only the salivary glands, the pancreas, testes and ovary, but also extend to the central nervous system and other organs. A fatal termination, however, is extremely rare.

In the milder cases the local symptoms are the first to attract attention. There is pain in the region of the parotid, increased by movements of the jaw, by pressure, and sometimes by the presence of acid substances in the mouth. In the more severe cases constitutional symptoms as fever, headache, vomiting, pains in the back of the limbs, may precede by 24 to 48 hours pain and swelling in one or both parotid. Occasionally, swelling of the submaxillary or sublingual glands occurs before that of the parotid, and in rare instances these may be the only glands affected. The constitutional symptoms usually last from three to five days, the swelling subsides slowly over the ensuing one or two weeks. Symptoms of extension to other structures usually develop from four to seven days after onset of the parotitis, when this swelling is beginning to subside. Occasionally, involvement of the salivary glands is minimal or unnoticed and the clinical manifestations are due to invasion of the testes, ovaries, pancreas or central nervous system.

Among males from 15 to 25 years orchitis is a common complication, occurring



in one out of every four or five cases. The affected testes may undergo atrophy to some extent but complete sterility seldom ensues owing to the rarity of bilateral involvement. The analogous infection of the ovaries (ovaritis) in mature females is much less frequent. Involvement of the pancreas, which is still less frequent, is indicated by persistent nausea, abdominal pain, and tenderness.

Estimates of the frequency of meningo-encephalitis range from 0.5 to 10 per cent of the cases of parotitis. Symptoms vary in pattern and severity from those of a mild meningitis to those of a severe encephalitis. It seems not unlikely that there is an increase in the lymphocytes in the cerebrospinal fluid in a large proportion of cases of mumps whether there is definite clinical evidence of meningeal involvement or not. Mumps meningo-encephalitis without parotitis is by no means rare. Kilham and others (1949) have recently called attention to the possible confusion of this condition with nonparalytic poliomyelitis.

Johnson and Goodpasture (1935) proved conclusively that mumps is due to a filtrable virus which is present in the saliva, at least in the early stages of the disease, and capable of producing a comparable parotitis in *Macaca mulatta* monkeys when inoculated directly into Stensen's ducts.

The susceptibility of monkeys (species *Macaca*) to mumps infection was confirmed by later workers. In 1942, Enders and Cohn described a complement-fixation reaction employing an extract of infected monkey parotid glands as virus antigen, and in the following year the use of this same antigenic material in a skin test for susceptibility to mumps. A more available source of antigen was required before these tools could be put to practical use. It came when Karl Habel (1945) reported cultivation of mumps virus in developing chick embryos. This was confirmed and extended by Levens and Enders (1945) who demonstrated that the virus was principally concentrated in amniotic sac material. The way was thus opened for advancement of studies of the properties of the virus itself and of immunological methods designed to recover and identify the virus, to provide diagnostic tests and to determine susceptibility and immunity.

The infective particle in allantoic fluid of the chick embryo is probably in the range of 90 to 135 *mu*. It is inactivated by heating for 20 minutes at temperatures of 55° to 60° C and infectivity is lost within 12 hours after the addition of 0.1 per cent formalin, or by appropriate irradiation with ultraviolet light. The virus, like that of influenza and Newcastle disease, possesses the property of agglutinating chicken erythrocytes. This hemagglutinating activity is specifically inhibited by high dilutions of serum of man and rhesus monkeys convalescent from mumps (Robbins and others, 1949). A practical technic has been devised which permits demonstration of development of specific antihemagglutinin in human or monkey sera. Similarly, amniotic fluid provides a source of antigens for use in a complement-fixation test (Henle and others, 1948). Both antihemagglutinin and complement-fixing antibodies appear in the blood early in the disease and reach maximum titers the second or third week. An increase in titer by a factor of 4 or more has diagnostic significance with either test. Immune sera also possess the property of neutralizing virus in the mixtures incubated and inoculated into allantoic sac of eggs (8-day embryos) (Habel, 1951).

The use of inactivated mumps virus antigen in allantoic fluid as a skin test has been explored (Habel, 1952; Henle and others, 1951). This technic is a research procedure and has not yet been standardized. A high degree of correlation

has been found between the positive skin test and the positive complement-fixation test. From 70 to 80 per cent of individuals giving a history of having had mumps are positive by one test or the other. Neither a positive complement-fixation reaction nor a positive skin response affords absolute assurance of resistance to mumps, but the incidence of infection among such individuals was found to be less than 2 per cent, whereas, under the same conditions of exposure, it was many times that in those giving negative reactions. From 17 to 27 per cent of individuals with negative histories gave either positive complement-fixation reaction or positive skin test, or both. This was interpreted as evidence of inapparent, unrecognized or abortive infections in the past or of defective memory.

**Vaccine.** Commercial vaccine is prepared from the allantoic fluid of chick embryos infected with a single strain of mumps virus. After inactivation of the virus with formaldehyde the vaccine is standardized with respect to immunizing potency. Reactions, if they occur at all, are usually mild and do not last more than 24 hours. The degree and duration of protection afforded by inactivated mumps vaccine of this type has not been determined. In a large scale experiment conducted by Habel (1951) there was evidence that the attack rate of mumps was consistently lower in the vaccinated than in the nonvaccinated comparable control groups.

**Prevalence.** The only known source of mumps virus is the saliva of an infected human being. The virus is probably present in the saliva from about 6 days before the onset of parotitis until about 9 days after. On the basis of studies made with the complement-fixation reaction, inapparent or unrecognized infections are not uncommon. The incubation period varies from about 12 to 26 days, most commonly about 18 days. Susceptibility begins in early childhood, although infants rarely have a clinical attack. Immunity following an infection is usually durable, second attacks are extremely rare. The age distribution of cases of mumps is somewhat older than that of the other common contagious diseases. Maximum incidence occurs in about the eighth or ninth year. When the age of 20 is reached about 60 per cent of individuals give a history of having had mumps. It is not unusual for individuals to escape infection until young adult life.

When introduced into a residential school or a military organization the infection spreads slowly and insidiously. During World War I there were 230,356 cases of mumps, as compared with 96,817 cases of measles, among 4,000,000 men in the U. S. Army. The noneffective rate for mumps was the third highest for all diseases, being exceeded only by the rates for influenza and gonorrhea. During World War II this disease was of much less importance among Army troops. This was not surprising in view of the tremendous increase in travel in this country resulting in decreasing isolation of rural areas where many persons formerly reached adult life without having had mumps. According to McGuinness and Gall (1944) epidemics occurred principally among groups of soldiers from the rural areas of the south and southwest. About one third of the patients were moderately to seriously ill with orchitis or meningo-encephalitis, both of which occurred in some instances without an associated parotitis.

**Control.** Because of the communicability in the early stages before diagnosis can be established, of the indefinite duration of the infective period, of the common occurrence of mild, ambulatory and missed cases, the spread of mumps cannot be prevented under ordinary circumstances. It is customary in most communities to isolate cases of the recognized disease until swelling of the salivary glands has sub-



sided. In schools and institutional groups it may be desirable to attempt to retard dissemination by restrictions placed upon exposed susceptible contacts. Such contacts may be permitted to attend classes for ten days following the date of earliest exposure and excluded for a two-week period thereafter. However, the opinion is held with equal cogency that to attempt to prevent infection with mumps during childhood is a disservice. The disease tends to be more severe in adult life and carries with it the risk of sterility. According to this view, there is no good reason for trying to interfere with natural exposure. Vaccination would seem to be indicated for susceptible parents who may be exposed to infected children and adults in institutional, labor, industrial or other special groups among whom the disease may become epidemic. The value of the use of immune serum or immune globulin has not been established. A study made during World War II by Gellis and others (1945) led to the conclusion that gamma globulin derived from pools of normal human plasma administered to patients with parotitis of 24 hours duration or less was ineffective in reducing the incidence of orchitis complicating mumps in the dosage used (5 ml.), whereas gamma globulin (20 ml.) from mumps convalescent serum appeared to be highly effective in this respect.

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#### COMMON RESPIRATORY DISEASES

##### *(Acute Minor Respiratory Infections)*

A number of diseases have been grouped together under the designation common respiratory diseases or acute respiratory infections. Progress has been made in recent years in separating out of this group some of the entities of which it is composed. Some still cannot be readily identified. Their symptomatology is so protean as not to permit differentiation. The tissues of the respiratory tract have a limited capacity to react defensively against noxious agents. The area or areas of the mucous membrane which are involved exhibit some measure of congestion, edema, altered



secretory activity of mucosal cells, outpouring of leukocytes and, in some instances, cellular destruction in the formation of an inflammatory membrane. An indication of this process is a nasal discharge usually thin and serous at first, sometimes viscid and frequently becoming mucopurulent. Subjectively, the individual experiences indisposition, lassitude, headache, chilliness, fever, general aching, weakness and prostration, with varying intensity. Sneezing and dry or productive cough may or may not come into play as a clearing mechanism. The process occasionally goes on to the involvement of the terminal bronchioles and alveoli of the lungs. Thus, the clinical pattern shows an endless variation both as to the areas of principal involvement and severity of symptoms. These patterns have frequently been designated by anatomical reference as rhinitis (coryza), pharyngitis, tonsillitis, tracheitis, bronchitis and pneumonitis (pneumonia), or some combination of these.

Much more satisfactory, though difficult, is a classification based on etiology. By careful observation and description and the use of laboratory procedures, one after another of the causes have been identified but many still remain to be determined. In general, the known causes may be grouped as noninfectious and infectious agents.

The noninfectious agents are physical, chemical, and nervous stimuli. It is a common experience that the nose becomes congested in a warm stuffy room; it secretes mucus freely, "runs" on a cold day. Engorgement of the mucous membrane can be reproduced as a result of the reflex nervous stimuli. Mudd and Grant (1919) have shown that chilling of the skin causes vasomotor contraction and ischemia of the mucous membrane of the tonsils, palate, and pharynx, as well as the skin, with a drop in temperature and a subsequent increase in bacteria on these parts. On rewarming the subject, the tonsils tend quickly to recover their blood supply, and in some instances actually become hyperemic; the skin returns to about its normal condition, but the palate and pharynx remain somewhat ischemic. An irritating gas, such as chlorine, will cause profuse lacrimation and nasal discharge with irritative cough. The dusty atmosphere of a barn at haying time will produce much the same effect. "Rose cold" or hayfever is a manifestation of allergy initiated by contact of the respiratory mucous membrane with antigens, contaminating pollens and dusts, causing asthma when the reaction involves the bronchioles. With the exception of hayfever and asthma, reactions to these physical, chemical, and nervous stimuli are usually of relatively brief duration. They are, nevertheless, frequently classified as "colds." In no small measure they are responsible for the reputation of miraculous remedies which advertisements claim cure a cold "if taken early enough."

More important are the biologic agents, the microparasites of various genera and species which are capable of initiating an infectious process on the mucous membrane of the upper respiratory tract. Against many of these the evidence is clear cut and definite. Some have been only partially incriminated in their causative role. Others remain yet to be discovered. Differential diagnosis depends not only on the epidemiological and clinical pattern but very largely upon diagnostic laboratory procedures, which are not always readily available. Due consideration is always given first to the possibility that an acute respiratory illness in an individual is the beginning of, or a mild clinical attack of, some well known disease, for example, whooping cough, diphtheria, measles, streptococcal sore throat. More rarely, and in certain limited areas, consideration must be given to more unusual diseases, such as "Q" fever, coccidioidomycosis, psittacosis, acute lymphocytic choriomeningitis.

Among the first and foremost agents which have been proved to be the cause of acute respiratory disease are the influenza viruses. Recently, it has been appreciated that these viruses are responsible not only for epidemics but also to some extent for the endemic occurrence of acute respiratory disease.

When the known causes have been excluded from consideration, there remains a large number of acute respiratory infections, the causes of which are in the process of delineation. It has recently been suggested (Dingle, 1948) that this group be divided tentatively into four categories which may represent separate etiologic entities, namely, the "common cold," nonbacterial exudative pharyngitis and tonsillitis, acute respiratory disease undifferentiated or "ARD," and primary atypical pneumonia.

### COMMON COLD

In reviewing previous work on the "common cold" one must constantly keep in mind that the definition of this condition has varied widely (Thompson and Thompson, 1932). In the older literature it was a much more inclusive designation than it is today. It is now defined as a mild, self-limited, afebrile respiratory illness, characterized by catarrhal inflammation of the mucous membranes of the nose, the sinuses and contiguous structures of the upper respiratory passages. The prominent features are coryza, lacrimation, conjunctivitis, dry and scratchy throat, an irritative cough, swollen and congested mucous membranes, and a normal leukocyte count. But considerable clinical variations are seen in "colds" as they occur in different persons and in the same person at different times. Some appear to be localized in the nose and sinuses or the throat; others, regardless of the area of initial involvement, spread to infect almost the entire respiratory tract. Some are mild without systemic reactions; others are more severe, with associated fever, chilliness, malaise, and other constitutional symptoms. Clinically, then, diagnosis of the "common cold" encompasses illnesses which may represent variations of a single disease entity or which may be due to multiple agents.

**Etiology.** The investigations of Kruse (1914), Foster (1917), Dochez and others (1930), Long and others (1931), demonstrated that coryzal types of illness of a short period of incubation could be transmitted to well human beings and chimpanzees by inoculation of bacteria-free washings of the respiratory tract of patients with colds. Investigations of the Commission on Acute Respiratory Diseases (1947a, b) have confirmed and extended these studies. Andrewes and his associates (1949) have more recently reported the results of a large series of human experiments carried out under carefully controlled conditions.

**Characteristics of Cold Viruses.** Filtration experiments (Andrewes, 1949) suggest that one infective particle, presumably a virus—20 to 50 $\mu$  or less—is considerably smaller than the influenza virus particle. These filtrates suffered no demonstrable loss of infectivity for human subjects on storage in sealed ampules in dry ice at  $-76^{\circ}\text{C}$  for two years; at  $10^{\circ}\text{C}$  they survived at least 27 days, and at  $4^{\circ}\text{C}$  for three days.

Aside from the chimpanzee no other animal has been found that is susceptible to infection with cold virus. Andrewes and his associates (1949) have attempted in vain to produce colds in mice, rats, guinea pigs, cotton rats, voles, rabbits, hamsters, grey squirrels, hedgehogs, ferrets, kittens, parrots, chickens, pigs, green monkeys, red patas monkeys, capuchin monkeys, and sooty mangabey.



There have been many attempts to grow cold virus in tissue culture. Ward and Proctor (1950), in three controlled experiments, found that signs and symptoms similar to those of the common cold developed in 14 of 23 individuals receiving virus material isolated from human sources and transmitted through the allantoic sac of the chick embryo for five passages. On the other hand, in extensive trial Andrewes and his collaborators (1949) were unsuccessful in attempts to pass the virus in fertile hen's eggs.

The complications of the common cold—sinusitis, adenitis, bronchopneumonia—are caused by secondary invasion of the inflamed mucous membranes by the bacteria which happen to be present in the upper respiratory tract—streptococcus, staphylococcus, pneumococcus, influenza bacilli.

**Observations on Experimental Colds.** From observations made upon experimental colds produced in human beings by Andrewes in 1949, the incubation period was normally two or three days, with a range of one to six days. Nasal discharge was an almost invariable symptom, was usually thin and serous at first, but sometimes viscid from the beginning. Twenty-four hours after onset it was commonly mucopurulent. Malaise and headache were common at the onset, but fever was exceptional. About one third had cough, usually unproductive. Postnasal discharge was uncommon; so were complications. The symptoms were rather mild and of brief duration, usually less than six days. The infectious agent was found in nasal secretions 24 hours before the first symptoms of the cold. How long it may persist has not yet been determined. There is no direct evidence that cold viruses can survive long outside the body.

**Immunity to Cold Viruses.** The Commission on Acute Respiratory Disease (1947b), inoculated five volunteers with a cold virus and produced colds in four of them. Meanwhile, they stored some of the same virus until 19 days later when these colds had cleared, they then used the stored virus to challenge the immunity of the same five persons. Again, four out of five developed colds; one who had resisted the first inoculation this time was a victim. This result does not necessarily mean that immunity to colds is so short under natural conditions. The dose of virus given experimentally was probably many thousand times as big as any conceivable natural dose. In Andrewes' experience, about 40 per cent of volunteers who were experimentally exposed to a cold virus proved to be resistant, though hardly any of them claimed to be free from colds throughout the year. Many observations attest that the resistance to colds in individuals varies from year to year (Gafafer and Doull, 1933) and for no apparent reason. Some individuals may have colds each year, others have none. The available evidence suggests that resistance acquired through having experienced an infectious cold is of variable degree and duration.

**Predisposing Causes.** It has long been assumed that colds are induced in those who are "run down," fatigued and exposed, with depressed vitality due to poor hygiene, loss of sleep, insufficient food and other depressing influences. Lesions of the mucous membrane, deviated septum, and other malformations, enlarged tonsils, adenoids and polypi, are all set down as inviting congestion and infection, in short, predisposing to colds. However, when the subject is studied, no particular significance seems to attach to these factors. Thus, according to Gafafer (1932), those with tonsils and adenoids and those without tonsils and adenoids present no significant difference with respect to frequency, severity or type of attack. A study by the same investigator of groups with brown eyes and with blue eyes showed no significant



differences; and the same is true of groups of Jews and non-Jews. Palmer found no evidence of association between size of frontal sinus and the number and duration of attacks. Doull and others (1931) presented an analysis of the frequency and severity of attacks in persons classified, on otolaryngological examination, as normal and abnormal with respect to tonsils, adenoids, breathing space, turbinates and maxillary sinuses. Taken as a group, individuals exhibiting one or more abnormalities were found not to suffer a greater frequency of attack than normal persons. Hardening procedures, such as sleeping with windows open and exercising outdoors, appear to exert no significant effect. A study of the effect of irradiation with ultra-violet light by Doull and others (1931) gave a slightly higher incidence for the irradiated group, and severe cases were just as frequent in the irradiated as in the control group. There is no convincing evidence that drafts produce an infectious cold.

To summarize, very little is known about the factors which depress resistance to the common cold.

**A. P. C. Viruses.** Hilleman and Werner in 1949 reported recovery of a hitherto unknown viral agent, designated as RI-67, from throat washings of a patient suffering from an acute respiratory illness. It grew and caused characteristic cytopathogenic changes in tissue culture containing human epidermoid carcinoma (HeLa) cells. Similar but antigenically different strains were isolated by this technic in other outbreaks of respiratory disease (Huebner and others, 1954). These strains have been called the A. P. C. (adenoidal-pharyngeal-conjunctival) group. Six types have been recognized. The pathogenic potentialities to the human host are being explored.

**Mode of Transmission.** The virus is present in the secretions of the upper respiratory tract during the early stages of a cold. The infection is presumably conveyed from person to person by coughing, sneezing, and talking. The relative importance of conveyance by droplets, by contaminated articles and by air-borne droplet nuclei, is unknown. It is attested by Arctic explorers that conversational contact in the open air is sufficient to effect transmission.

**Prevalence and Distribution.** According to Kneeland and Dawes (1932) during the first few months of life colds are relatively infrequent, perhaps because of protected existence. Gradually, their frequency increases. Maximum frequency occurs during the second year and remains at a high level under five. The incidence gradually declines throughout childhood to reach a more or less stable level experienced during adult life. In Baltimore studies by Van Volkenburgh and Frost (1933), the attack rate per 100 persons at all ages observed for one year was 307. This is in approximate agreement with the findings of other observers that about three colds in one year is average experience.

At times colds spread through whole families in rapid succession. At other times a single member of the family is affected and there is no further spread to associates.

Limited data are available which permit a comparison of the frequency of the common cold in populations otherwise comparable but living in different latitudes. The nearest approach to this is the study of Frost and Gover (1932) of acute minor respiratory disease in civil population groups in the United States. The data collected at that time suggested that there was very little difference in the experience of the population surveyed in communities of such wide geographic distribution as Washington, Baltimore, New Orleans, and San Francisco. Attempts to relate the

incidence of colds directly to temperature, rainfall, humidity, and sunshine have not been convincing. On the other hand, there is much evidence to indicate that in the North Temperate Zone the prevalence of minor respiratory infections shows a distinct seasonal pattern. If the experience of the U. S. Army can be taken as representative, the curve shown in Figure 1-4 indicates the annual cycle of respiratory disease incidence. The rates are based on cases per 1,000 strength per year for common respiratory disease and influenza combined. Highest incidence is reached in the winter months between December and April; lowest frequency is registered in the summer months from June to September (Health of the Army, 1947). This

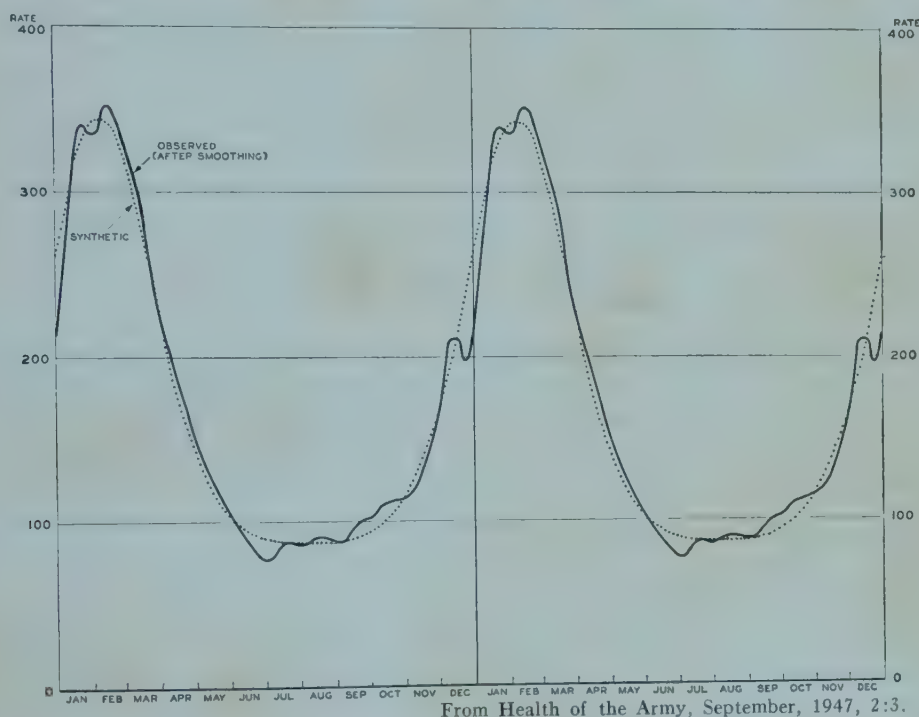


Fig. 1-4. Annual cycle of respiratory disease incidence, United States, January 1924-January 1947. Comparison of the synthetic annual cycle with the date (after smoothing) from which it was derived.

Note: Ordinates are rates in cases per thousand strength per year for common respiratory disease and influenza combined.

is a smooth curve obtained from a very large experience extending over 23 years. From the character of this seasonal curve, the inference may be drawn that the conditions of living during the colder months of the year are more favorable to the dissemination of acute respiratory diseases.

Colds normally cease to trouble an isolated group, such as a band of Arctic explorers soon after they left civilization behind. Smillie and his associates and Paul and Freese (1933) studied common colds in isolated places, such as the Northwest River, Labrador, and Spitzbergen, Norway. The natives are susceptible but free from colds until the arrival of a stranger or ship. Once introduced the infection spreads widely, but disappears at the end of the open season. In Tristan da Cunha, visiting ships bring with them epidemics of colds, but these are brought only by ships from Capetown, the voyage from which lasts not more than 12 days. Ships coming from Panama around Cape Horn do not bring colds; perhaps the virus normally dies out



within a few weeks (Andrewes, 1949). These observations suggest that there are no inapparent infections of long duration or carriers who harbor the viruses from one season to another, at least in these subarctic regions.

In communities, civil, military and institutional, which are affected by the ordinary travel and intercommunication of people, the seasonal rise and fall in the incidence of colds is characterized by a series of oscillations due to a succession of epidemic periods of varying magnitude (Van Volkenburgh and Frost, 1933). In studies of the residential schools in England (School Epidemics Committee, 1938) data were presented to indicate that quite uniformly there were epidemic peaks in the incidence of minor nasopharyngeal infections from two to four weeks following reaggregation of students after a holiday period spent at home.

**Prevention.** Exposure to the infectious agents which cause the common cold is unavoidable for all who live within the bounds of civilization. The frequency of such exposure is modified by habits of living and environmental circumstances. It is apparently greater during the colder and more inclement months of the year when people are brought together in groups or crowds within doors a greater proportion of the time under conditions of poor ventilation. The possibilities of prevention by disinfection of indoor air are discussed in the next chapter.

One would expect that in a community in which a high level of personal hygiene prevails with regard to coughing, spitting, sneezing and use of handkerchiefs, and in which a high degree of cleanliness is maintained with respect to hand washing, and washing of common drinking glasses, dishes, eating utensils and other commonly used objects, that there would be some reduction in transmission. Up to the present, however, there has been no conclusive demonstration that this is true.

Courtesy requires that the individual who has a cold have regard for his fellow and take all reasonable precautions to prevent dissemination. On the other hand, it is humanly impossible that constant vigilance be maintained in this matter, even by individuals who are fully cognizant of the ways and means of transmission. So far as present knowledge permits statement, a mild cold or one in its incipency, causing practically no inconvenience, may be as infectious as a severe cold with sufficient constitutional reaction to require bed treatment.

**Chemoprophylaxis and Treatment.** Suppression or modification of the infectious type of common cold by the administration of drugs is a subject about which much has been written and little been scientifically proved. The Committee on Public Health Relations (1951) has advised that the value of antihistaminic drugs in treating the common cold is negligible. Discrete treatment with antibiotics may in some measure reduce the incidence of secondary bacterial complications. Other measures may make the patient more comfortable.

**Cold Vaccines.** During the era when the common cold was thought to be due to the bacteria commonly found in the upper respiratory tract, much was written on the subject of prophylaxis by vaccines. These were made from single or mixed strains from stock or autogenous cultures. They contained staphylococci, streptococci, micrococcus catarrhalis, Pfeiffer's bacilli, pneumococci, and other organisms. Where the observations were carefully controlled there has been no convincing evidence that they were of value (Diehl and others, 1940).

The development of an immunizing procedure based upon the use of preparations of the virus or viruses which are thought to cause the common cold is distinctly in the realm of experimental study.

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## EXUDATIVE TONSILLITIS AND PHARYNGITIS OF UNKNOWN CAUSE

Differentiated from the common cold on one hand and from streptococcus sore throat on the other, this is a clinical condition tentatively identified as "exudative tonsillitis and pharyngitis of unknown etiology" (Commission on Acute Respiratory



Diseases, 1947a). This differentiation has been suggested by a number of investigators (Stuart-Harris and others, 1938; Francis, 1939; Keith and Carpenter, 1946). It is generally a mild disease of short duration. The onset is ordinarily gradual, and early complaints in the majority of patients are those of feverishness, headache, and anorexia. Symptoms of sore throat, hoarseness and cough, often productive, are noted by 75 per cent or more of the patients and tend to reach great prevalence by the third or fourth day of the illness. Nasal symptoms are not common. On physical examination, the mucous membranes of the palate, the pharyngeal wall and tonsils show varying degrees of injection, which is usually not severe. The exudate is usually small in amount and appears as gray or yellowish individual spots which are pinhead in size. Larger patches of exudate may develop, but rarely do they become confluent. Often the exudate forms over swollen lymphoid follicles on the pharyngeal wall. Enlargement of the cervical lymph nodes may be present in approximately one fourth of the cases. Involvement of the lungs occasionally occurs. In approximately two thirds of the cases total leukocyte counts are below 10,000 and the differential formulas are normal. Bacteriologic and serologic examinations give no evidence of beta hemolytic streptococcus infection. The average peak of temperature is between 101° and 102° F, and the fever ordinarily declines by lysis. The duration is approximately five days and convalescence is usually uneventful. The cause of this syndrome has not been determined nor have direct attempts been made to transmit the infection to man. At the present time, the disease can be diagnosed only after the exclusion of the common bacterial infections, by clinical, cultural and serologic methods. The problems of prevention are essentially similar to those of the common cold.

#### UNDIFFERENTIATED ACUTE RESPIRATORY DISEASE

On the basis of experience during World War II, the Commission on Acute Respiratory Diseases (1947b) proposed that a category designated as undifferentiated respiratory disease be tentatively recognized as clinically, immunologically, and epidemiologically distinct from the common cold and influenza. As seen in hospitalized recruits, it is a mild respiratory illness with gradual onset. Most frequent complaints are those of feverishness, chilliness, and headache. Symptoms of malaise, anorexia and nasal involvement appeared in approximately one-half the patients. Sore throat is common but is mild in degree in comparison with that encountered in patients having exudate in the throat. Minimal hoarseness and cough are common, although fewer than half of the patients have productive cough or pain in the chest. On physical examination, the patient rarely appears to be severely or even moderately ill. Physical signs are remarkably few and are usually noted in less than half the patients. Nasal obstruction, mild injection of the pharynx and palate, and lymphoid hyperplasia on the pharyngeal wall are most frequently found. Edema of the mucous membranes, cervical adenopathy and thoracic rales are present in approximately 10 per cent of the patients. The febrile course is short, from two to four days, and the average maximum temperature is about 101° F. Constitutional symptoms subside with defervescence, but symptoms referable to the respiratory tract when present, tend to persist for one or two weeks. Leukocyte counts are usually within normal limits, and cultures of the throat reveal only normal bacterial flora.

It appears, therefore, that this syndrome may be a clinical entity of nonbacterial

origin, which differs from the common cold or acute coryza. Mild respiratory illnesses exhibiting similar characteristics have been produced in human volunteers as a result of exposure to throat washings from a representative donor (Commission on Acute Respiratory Diseases, 1947c). Reinoculation of experimental subjects with filtered washings from the same donor produced no illness. It thus appeared that undifferentiated acute respiratory disease in contrast with the common cold is followed by homologous active immunity. Success of inoculation of these experimental subjects at later periods with filtered throat washings from a patient with severe common cold and from a patient with atypical pneumonia, however, failed to demonstrate heterologous immunity to the agents producing the two latter types of respiratory disease. This study in human volunteers indicates that a mild disease of the respiratory tract, characterized by an incubation period of five or six days, and a predominance of pharyngeal symptoms and signs can be transmitted to man. This disease not only has a longer period of incubation than the common cold but also appears to be immunologically distinct. The causative agent is filtrable and is presumed to be a virus.

This condition was further differentiated upon epidemiological evidence (Commission on Acute Respiratory Diseases, 1946). It appears to be the condition which is largely responsible for acute respiratory disease in recruits (Sartwell, 1951). When recruits are brought together in training units during the early winter and spring months, an epidemic spread of this condition, reaching its peak usually in the third or fourth week of formation of the training unit is a common experience. The rates among recruits are several times as high as those among seasoned troops. When recruits are brought together for training purposes during the summer and early fall these epidemics do not ordinarily occur.

**Prevention.** The problems of prevention are those of the prevention of acute respiratory infections in general. They are discussed in Chapter 2. The results of antibiotic treatment are equivocal.

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#### PRIMARY ATYPICAL PNEUMONIA, ETIOLOGY UNKNOWN

(*Virus Pneumonia, Acute Pneumonitis*)

During recent years, there has been an increasing interest in the occurrence of cases of respiratory infection associated with pulmonary lesions in which the common pathogenic bacteria do not seem to play any etiologic role. The name "virus"



pneumonia has been applied rather loosely to this group. This designation, however, would include pneumonia occurring in the course of such well known diseases as measles, smallpox, psittacosis, or influenza. Excluding these from consideration, there remains a syndrome which appears to be clinically and epidemiologically distinct but which may have a multiple etiology. Until etiology is clarified and more specific diagnostic laboratory tests become available, it is proposed that this syndrome be designated as "primary atypical pneumonia of unknown etiology." The infectious process does not always involve the pulmonary area and in its milder manifestations in individuals is indistinguishable from the common cold and acute undifferentiated respiratory disease.

There is no reason to believe that this is a new syndrome. In its more severe manifestations, as a form of pneumonia, it was described clinically and pathologically as long ago as 1872 (Dingle and Finland, 1942). Since that time it has been designated variously as "acute influenzal pneumonia," "acute pneumonitis," "acute interstitial pneumonitis," "atypical pneumonia with leukopenia," "atypical bronchopneumonia of unknown etiology."

**Clinical Characteristics.** This syndrome is characterized by gradual onset and benign course. In some patients the constitutional symptoms—headache, chilliness, malaise, fatigue—are prominent in the early stages of the illness and gradually increase in severity. In others, the illness begins as a localized infection of the respiratory tract as indicated by dryness and soreness of the throat, and by cough. Coryza may be noted in about one third of the cases. As the disease progresses, the cough ordinarily becomes productive of greenish yellow mucopurulent sputum. Rarely is the sputum mixed with blood. Physical examination early in the illness usually reveals little beyond mild infection of the pharynx. Later, however, medium fine, sticky rales and coarse rales are characteristically heard in the involved area of the lung. X-ray examination provides evidence of pulmonary involvement. Infiltration is usually light and patchy and peribronchial in distribution. The x-ray shadows may be migratory. The average illness is about five to seven days' duration. Complications are infrequent and the prognosis is excellent despite the lack of specific therapy. The uncomplicated pneumonia is rarely fatal. The case fatality rate is estimated to be less than 0.1 per cent.

**Etiology.** The causation of primary atypical pneumonia was extensively investigated in a number of laboratories during World War II. Attempts to establish in animals an infection which could be related immunologically to the human disease had for the most part been unsuccessful. Studies of the Commission on Acute Respiratory Diseases of the U. S. Army (1946 and 1947a, b), demonstrated that primary atypical pneumonia can be transmitted to human volunteers by bacteria-free filtrate of sputum and throat washings. Clinically, the experimentally induced infections resembled the naturally acquired disease. The incubation period was from seven to 14 days. There was no evidence that bacteria played any part in initiating the infection or as secondary invaders. Thus, clinical and experimental evidence indicate that primary atypical pneumonia is a virus infection of the respiratory tract. Further investigation is necessary, however, to determine whether or not one agent or more is concerned in the production of the naturally acquired disease.

**Laboratory Diagnosis.** It is necessary to exclude first, by appropriate diagnostic procedures, other diseases which may present essentially the same syndrome. The

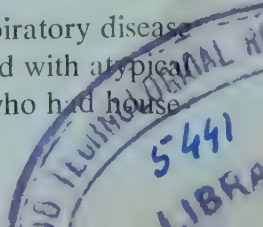
diagnosis is established partly by exclusion of other causes. However, two empiric laboratory tests have proved to be of some value. Both are agglutination reactions in which the acute and convalescent specimens of the patient's serum are examined in order to demonstrate a rise in antibody.

The first, or cold agglutination test, utilizes O human red blood cells as antigen. Agglutination takes place only at a cold, usually icebox, temperature. On warming to 37° C the hemagglutinin disappears. The second test is the agglutination of streptococcus MG which is carried out in essentially the same fashion as other agglutination tests. The proportion of patients whose sera show significant increases in titer for one or the other of these agglutinating antibodies, or for both, has varied in several reports of a series of cases. In general, approximately 50 per cent of the patients show positive reactions. The two tests appear to be directly correlated with the severity of the illness and the extent of pulmonary involvement. Each provides a retrospective confirmation of diagnosis of primary atypical pneumonia, since the antibodies do not develop until the second or third week of illness. Moreover, failure to demonstrate antibodies does not exclude the diagnosis.

**Occurrence.** As pointed out by Francis (1944), the apparent increase in the frequency of this form of pneumonia has been due to a number of developments in recent years. The greater use of the laboratory in identifying the bacterial agents in cases of pneumonia by pneumococcus typings and cultures of the sputum or blood has revealed an increasing number of cases in which significant bacterial agents were not encountered. The widespread use of chemotherapy and recognition of the prompt response of pneumococcal and streptococcal pneumonia to sulfonamides suggested that processes that did not respond were of different etiology. There has been a reduced incidence of pneumonia due to pneumococcus. Last, and perhaps most important, the availability of x-rays in establishments where large groups of individuals are drawn together, as in schools, industry, military forces, has aided in the recognition of pulmonary involvement in many instances which could not be so interpreted on the basis of physical examination or clinical course. The differentiation of this disease from other acute respiratory infections depends very largely upon characteristic x-ray evidence. Because of these considerations, data regarding the occurrence of this syndrome are meager and fragmentary. Except for certain limited studies, its distribution is largely unknown. These studies have come very largely from Army camps, schools, and colleges.

From these accounts it seems that primary atypical pneumonia is characteristically sporadic in occurrence but at times becomes so frequent as to constitute epidemics. The following accounts are illustrative. Bowen in 1935 discovered a yearly attack rate which varied from less than one to approximately six per 1,000 in white troops during a three-year period, in Honolulu. Reimann and Havens (1940) observed 25 cases among a hospital staff of 813 persons. Smiley and others (1939) reported an incidence at Cornell University of approximately 9 in 1,000 for the academic year 1937-38. Gallagher (1941) reported an epidemic of 87 cases among adolescents. Daniels (1942) reported 13 cases in a school of about 90 girls, during a six-week period, or almost 15 per cent.

Many of the observers remarked upon the occurrence of mild respiratory disease without pulmonary lesions demonstrable by x-ray in persons associated with atypical pneumonia. Reimann (1938) noted that in a group of five patients who had house-





hold contact there were two cases of severe infection and three with mild illnesses which might have been called common cold or febrile catarrh. In the epidemic at Jefferson Hospital, Reimann and Havens (1940) describe 407 cases of respiratory disease in a staff of 813. By far the largest proportion (75 per cent) of these were mild infections, and the patients remained ambulatory. About 100 were sick enough to go to bed. Clinical and roentgenological diagnosis of acute tracheobronchitis was made in 25 and of pneumonia in 25. Apparently cases of the mild form (nasopharyngeal laryngitis), 88 per cent, far outnumbered those of the severe form (with pneumonia), 12 per cent. Gallagher (1941) noted 11 cases of mild infection without pulmonary involvement that epidemiologically both preceded and followed cases of so-called pneumonia. Longcope (1940) has observed that patients may apparently contract a severe form of infection from those who have had a mild attack or that the reverse may occur.

During World War II, Dingle and others (1944) made a careful clinical, epidemiological, and etiological study of primary atypical pneumonia during a period of high prevalence at Camp Claiborne, Louisiana. Data regarding the manner of occurrence of this disease among the troops stationed at this camp were collected from February, 1941 to March, 1942. Cases were occurring throughout this period but the incidence rose to a sharp peak in July, 1942. The highest attack rate sustained by any organization was that for troops attached to the station hospital. Their rate was two or three times as high as that for any other organization. Among these troops, the attack rate for those whose duties brought them into contact with patients was seven times as high as for those who had casual or no contact with patients. With this exception, focal concentration of cases in companies and regiments was rare. Atypical pneumonia occurred in nearly every organization stationed at the camp during the epidemic and endemic period. In one division of troops, the observed distribution of cases of atypical pneumonia among companies was approximately the same as might be expected from a theoretical distribution if cases had occurred at random. Only rarely could one case of atypical pneumonia be traced to another.

The experiences which have been reviewed, together with others, support the hypothesis that the causative agent is at times widely distributed in human populations. In the great majority of individuals the infection is of mild form without serious pulmonary involvement and is classified as a common cold. In the occasional individual the infection is manifested in its severe form as primary atypical pneumonia. In some epidemics the virus appears to be more virulent than in others. There is little knowledge regarding predisposing factors, such as chilling, fatigue, or preceding upper respiratory illness. The duration of immunity following the illness is unknown. There is little doubt that the infection is transmitted from person to person by some form of association. Duration of the infectious period is unknown and the incubation period is thought to be seven to 21 days, and most commonly about 11 or 12.

**Prevention.** At the present time, no specific control measures are available. Isolation of cases seems indicated largely as a protection to the hospital personnel but cannot be considered as an effective means of control of the disease. Problems of preventing spread are similar to those of the common cold and other acute

respiratory diseases. The possibilities of air disinfection will be more fully discussed in a subsequent chapter. Evidence of active immunization is not available.

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## INFLUENZA

The term "influenza" has had a popular and vague usage. It has been applied to common colds, acute catarrhal inflammation, brief febrile attacks of unknown origin, and even to gastro-intestinal disorders and nervous indispositions. When influenza sweeps over the world in pandemic form, it becomes the most serious and furious of epidemics on account of the large numbers attacked in a short time. There is a high incidence, with a comparatively low case fatality rate, but the mortality is high on account of the great number of cases. In the world-wide pandemic of 1918-1919, it is estimated that there were over 200,000,000 cases and that upwards of 10,000,000 deaths occurred in less than 12 months; in the United States alone there were more than 20,000,000 cases and about 450,000 deaths in less than six months. In India, 4,933,132 deaths from influenza were reported from June to November, 1918.

The early history of influenza is necessarily veiled in obscurity. Hirsch in his great work gives a summary of periods when influenza was pandemic. There is an account of an epidemic, probably influenza, recorded in 1173. Many outbreaks of "plague," some of them doubtless influenza, occurred long before this. The first authentic outbreak was described in 1510 by the famous physicians Willis and Sydenham. There have been about 80 epidemics, more or less authentic, since 1173. Fourteen pandemics have been recorded since 1510; they are those of 1510, 1557, 1580, 1593, 1729, 1732, 1762, 1788, 1830, 1833, 1836, 1847, 1889 and 1918—about four a century. The relation of sporadic and interepidemic outbreaks



to pandemics of influenza is not clear. Indeed the medical historian dealing with these epidemic phenomena can only surmise as to whether they are related or unrelated—whether they are of similar or dissimilar etiologies. Thus, up to recent years the practical definition of influenza (according to Major Greenwood) has amounted to this: "An apparently sudden disturbance of the public health by the occurrence of a very large number of cases of illness characterized as regards a majority by signs and symptoms affecting the respiratory tract."

Nonetheless, the clinical, pathological, and epidemiological descriptions have become increasingly representative and precise during the past half century. Rarely, if ever before, in the annals of medicine, has a manifestation of epidemic disease been studied by numerous observers with so much ardor and reported with so much fullness as was the pandemic, perhaps the greatest of all influenza epidemics, of 1918-1919 (Jordan, 1927). The interest created by this startling phenomenon continued through the succeeding decades, leading to the discovery of the influenza viruses and the development of laboratory procedures permitting an etiologic differentiation. Contributions since 1933 have gone a long way toward explaining the biologic process which is called epidemic influenza.

**Clinical Definition.** Many descriptions of the signs, symptoms and course of influenza in different epidemics, times and places have been written. In its ordinary manifestations influenza merges with the common cold, febrile catarrhs, and other acute minor respiratory infections discussed in the preceding sections (Stuart-Harris and others, 1938; Francis, 1939b; Commission on Acute Respiratory Diseases, 1948b). The common features are an abrupt onset with chills or chilliness, fever, headache, muscular pains, prostration, cough, and nasal symptoms. The fever lasts from one to six days, usually two to three. Convalescence is usually uneventful, although it may be characterized by a considerable degree of depression and fatigability. From this general pattern, the clinical picture of epidemic influenza varies both towards mildness and towards severity. In the more severe cases the evolution of the illness is more rapid and intense. The constitutional reaction is prominent from the beginning. Prostration is out of all proportion to the clinical symptoms. There is a rapid and extensive virus invasion of the mucous membranes of the lower respiratory tract, of the trachea, bronchi, and bronchioles. This results in destruction of ciliated epithelium over considerable areas. With the accumulation of mucus, desquamated epithelium and inflammatory exudate conditions are created which are favorable to secondary bacterial invasion. The extent and character of the invasion is very largely a matter of chance depending upon potential pathogens which happen to be present in the patient's throat. This in turn is determined by the type of bacterial throat flora characteristic of the community at the time. Thus, secondary pneumonias may be predominantly due to hemolytic streptococci, to pneumococci, to the influenza bacilli of Pfeiffer or to other organisms. In extremely severe cases death may occur within 48 hours.

The proportion of cases of influenza which are severe and complicated by pneumonia varies with each epidemic and with each locality during the same epidemic. The mortality is determined by the proportion of the population attacked and the frequency of this complication.

**Etiology.** The first break in establishing the etiology of influenza came with the report of Smith and others (1933) that they had isolated from the nasal washings

of influenza patients a strain of virus (W.S.) which was pathogenic for ferrets by intranasal route. Further, they found that the serum from recovered ferrets and from convalescent humans would neutralize the infecting capacity of this virus. The following year this work was confirmed by Francis (1937) who was successful in isolating a strain of virus (PR8) from a patient suffering from influenza in Puerto Rico. The work was taken up by other investigators and virus strains were isolated in many countries in several epidemics. Francis (1940) recovered a strain (Lee) from an institutional epidemic similar to, but immunologically distinct from, the strains which had been previously studied. Subsequently, strains of the original type like PR8 and W.S. have been designated as influenza A and the strains of the Lee type as influenza B. Extensive work in many laboratories has established the validity of these two types in the causation of influenza.

The physical, chemical, and biological properties of these two virus types have been extensively investigated. Their host range has been explored; their pathological and immunological properties have been studied in man and animals; useful laboratory procedures for rapid recovery and identification of the viruses and for the demonstration of specific antibodies have been developed (Burnet and Clark, 1942). Most of the strains which have been recovered are related to these two types, but may differ from the prototype strains to some degree in their immunologic characteristics. However, a strain of influenza virus (called 1233) antigenically distinct from types A and B has been identified by Taylor (1949) and confirmed by Francis (1950) with the suggestion that it be classified as Type C.

**Virus Isolation.** Several methods are available for attempting the isolation of influenza virus from throat washings. The specimens should be obtained during the early phase of the illness. Virus may still be present in the secretions after defervescence and not uncommonly up to the sixth day after onset, but rarely later.

**FERRET.** The original isolations of the virus of influenza A and B were accomplished by using the ferret; although the ferret is an extremely susceptible animal for detecting influenza virus and elaborate laboratory facilities are required for its care and handling.

**MOUSE.** In the early work, Andrewes, Laidlaw and Smith and Francis found that mice were susceptible by intranasal inoculation to ferret adapted strains. Neither ferrets nor mice could be infected by the subcutaneous or intraperitoneal routes. The mouse is less susceptible than the ferret upon original passage of human material. Nevertheless, it is possible to establish influenza virus from a patient's throat washings directly in mice without intermediate ferret inoculations. To establish the virus in the mouse as the primary host requires relatively longer series of intranasal passages at three- to four-day intervals and is slower than the other available procedures.

**CHICK EMBRYO.** W. Smith and F. M. Burnet in 1935 independently found the chick embryo was susceptible to infection with influenza viruses and showed that multiplication occurred in the chorio-allantoic membrane. This discovery afforded a method of studying the influenza viruses which was of inestimable value in advancing knowledge. For direct recovery of influenza virus from throat washings, inoculation of the hen's egg furnishes the simplest and most rapid method. Unfiltered throat washings to which chemotherapeutic agents (sulfonamides, penicillin, or



both) have been added give the highest proportion of successful recovery of the virus. While different routes of inoculation are used by individual investigators, the intra-amniotic route is the most sensitive (Hirst, 1948). Maximum virus titers are attained in the embryonic culture medium in about 48 hours in ten- to twelve-day-old embryos. Usually virus can be demonstrated in fluid from the first passage embryos but occasionally not until the second passage is carried out. Serial transfer through two to five egg passages may be necessary to increase the concentration sufficiently to produce the hemagglutinating effect. The hemagglutinating factor may be identified as the virus of influenza A or B or C with the aid of suitable antisera which specifically inhibit the agglutinating effect of the respective viruses.

Isolation of influenza virus from throat washings by any method is not a highly reliable method of determining the frequency of infection either in patients or in well individuals. If it be granted that an increase in serum antibodies indicates infection, then isolation of the agent was successful in approximately one half of the patients studied and in one eighth of well persons actually infected with the virus in the 1943 epidemic at Fort Bragg (Commission on Acute Respiratory Diseases, 1948a).

**Properties of the Virus.** Intranasal instillation of either type of virus leads to the development of the disease in man. However, subcutaneous or intramuscular injections of a fully active virus do not cause illness in human beings. Experimentally induced illness tends to be somewhat milder than the natural disease but in other respects does not differ significantly.

Influenza virus strains have been maintained in tissue culture for long periods. After more than 700 transfers a strain was found to have retained its pathogenicity for mice and ferrets (Francis, 1947). Infectivity is lost following heating to 56° C for a few minutes. These viruses are easily inactivated by irradiation with ultraviolet light, with formaldehyde, and numerous other reagents. The infectious titer of suspensions decreases in a few hours at room temperature but is little affected by storage at 4° C for a week. Purified preparations properly buffered may be held at 4° C for a month without showing any marked reduction in titer. Suspensions stored in sealed ampules at -76° C show no diminution in infectious titer.

Although highly purified by various procedures, it has not been possible to obtain influenza virus entirely free of extraneous material. On this account, knowledge of the chemical constitution of the virus, although it has been advanced, is not yet precise. However, many of the physical characteristics of the virus have been ascertained. As visualized under the electron microscope, these viruses appear as discrete particles of a relatively uniform size and shape. They are spherical, or nearly spherical, with diameters of 100 m $\mu$ . Both A and B virus strains cause so-called toxic reactions following intracerebral, intraperitoneal or intravenous injection in mice, guinea pigs, rats, and hamsters (Henle and Henle, 1946). The toxic property cannot be separated from the infective property, and is not the result of virus multiplication.

**Serological Diagnosis.** For the identification of influenza in animals and man, three serological procedures have been devised and developed. The principle involved is the demonstration of an increase in antibody titer for the viruses of influenza A or B or C by comparison of acute and convalescent sera. In all three the basic procedure involved is the same, i.e., the determination of the greatest dilution of

serum required to neutralize or inhibit the action of virus. Each test differs in the indicator employed.

1. **MOUSE NEUTRALIZATION TEST.** In this test the antibody content of a serum is estimated as the highest dilution that will prevent death within 10 days in mice inoculated with dilutions of serum to which has been added a standard number of lethal doses of virus (Francis and others, 1937). If the titer of the convalescent serum is four times or more higher than that of the acute it is evidence that the individual or the animal from whom the serum was obtained had had an infection due to the type of virus used in the test. While this test is dependable, it is laborious and time consuming.

2. **COMPLEMENT-FIXATION TEST.** The antibody content of a serum can be indicated by the degree to which the serum can be diluted and still fix complement in the presence of a standard quantity of influenza antigen (Friedewald, 1943). The antigen used is either virus grown in the fertile hen's egg or on an extract of the lungs of infected mice. When the complement-fixing titer of a convalescent serum is found to be fourfold or greater than the acute phase serum a diagnosis of influenza due to the type virus used in the test is warranted.

3. **THE AGGLUTINATION-INHIBITION TEST.** In 1941, Hirst observed that influenza viruses possess peculiar capacity to cause agglutination of red blood cells. Moreover, it was found that in the presence of antibody agglutination of erythrocytes by virus was inhibited. On the basis of these observations, a simple serologic method was developed (Hirst and Pickels, 1942). The antibody content of a serum is indicated by the highest dilution of serum that will neutralize or inhibit the agglutinating effect of a standard quantity of virus. An immune serum can be diluted to an extent proportional to its virus neutralization titer before its capacity to inhibit agglutination by a constant amount of virus is exceeded. The test thus measures either the level of neutralizing antibodies themselves or some other factor in the serum level which is closely parallel to such antibodies. This test is now used more extensively than any other.

**Human Susceptibility and Resistance.** Increased antibody may be demonstrated as early as seven days after the onset of illness. A maximum level is usually reached in two weeks, which persists for a few weeks longer and then begins to decline. After eight to 12 months the level drops to, or almost to, preinfection levels. New-born infants show sera with the same neutralizing activity as the mothers'. From six months to one year antibodies are usually completely absent; thereafter, the proportion of individuals with antibody shows an increase with age varying with local circumstances. The titer of antibodies in a serum is a reflection of experience of the individual with these influenza viruses in the recent and remote past.

As the virus has been recovered only from the respiratory tract and has not been detected in the blood stream at any stage of the infection, it has been generally considered that circulating antibodies, however measured, are not directly related to resistance to infection. Humoral antibodies, however, may indirectly determine resistance through the mechanism of nasal inactivating substances (Burnet and others, 1939; Francis and others, 1943). Little is known concerning nonspecific factors which may depress resistance temporarily. Thus, the titer of serum antibody is an indicator of susceptibility or resistance relative to virulence and dosage of the infecting virus strain and other factors. Practically, it has been found from observa-



tions on human beings both experimentally and naturally exposed that those with little circulating antibody are relatively susceptible and those with high titers relatively resistant to infection.

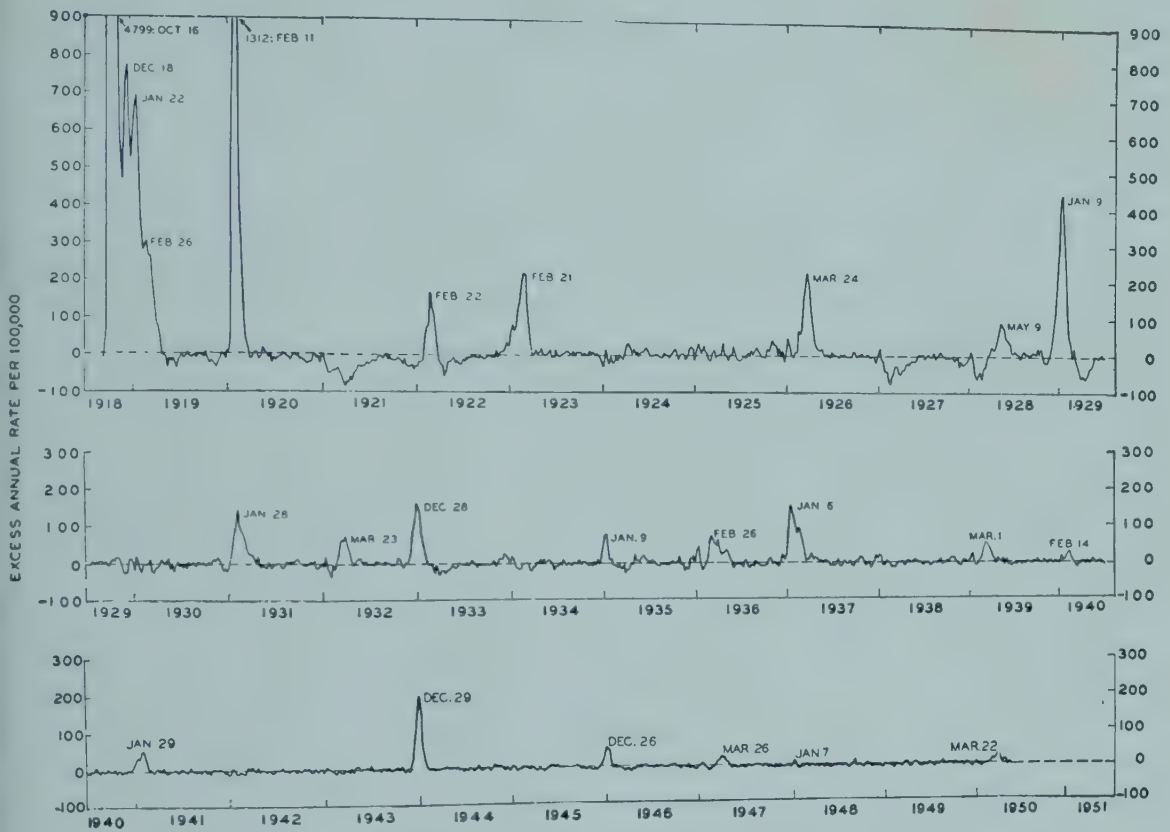
Studies by many investigators upon the distribution of antibody in the sera of persons during the course of an epidemic have demonstrated that a considerable proportion of infections are sub-clinical or inapparent symptomatically. For example, in an epidemic at Fort Bragg in 1943, hospital admissions comprised only half of the total of recognized cases of influenza A. Recognized febrile illnesses constituted only 21 per cent of the total infections as evidenced by increase in titer of antibody.

**Mode of Transmission.** The only known source of influenza A and B and C viruses is infected human beings. The infection may be expressed in clinical or inapparent form, the latter being much more frequent than the former. The virus is present in the respiratory secretions during the first few days of illness, rarely beyond the seventh day. Persistent carriers have not been demonstrated. As with other respiratory infections, transmission is effected during the acts of talking, coughing, or sneezing, and by secretions from the upper respiratory tract. The contagion may be passed from one individual to another by rather brief casual contact. Several investigators have demonstrated the possibility of air-borne infection for short distances under experimental conditions (Andrewes and Glover, 1941; Loosli and others, 1943). The relative importance of transfer by direct droplet spray, by air-borne droplet nuclei, and by indirect transfer by means of contaminated articles, dishes, and the like is unknown.

**Occurrence.** As its name implies, influenza is characteristically an epidemic disease. No part of the world is free from it for any long period of time. Every few years it occurs in widespread dissemination. These epidemics show a considerable variability in extent and duration. In a general way, reference may be made to those manifestations as pandemics, affecting large parts of the world as in 1918-1919 (Jordan, 1927); as waves affecting several countries and spreading internationally as with the B type virus in 1945-1946 (Andrewes, 1950); as minor waves limited very largely to a single country and its contiguous territory (Collins, 1930); and localized outbreaks affecting the smaller civil units only and sporadic groups of cases (Commission on Acute Respiratory Diseases, 1948b). Every gradation in prevalence occurs.

Because of the mildness of the disease and the lack of sharp clinical differentiation, official morbidity reports are notoriously unreliable as indices of prevalence. Over any long period of time and in any large geographic area what has happened can only be inferred from changes in mortality rates in respect to certain categories. Attention is concentrated upon deaths attributed to influenza and to pneumonia, since the two cannot be sharply distinguished. Figure 1-5, representing the excess annual death rates from influenza and pneumonia since 1917, reflects the experience of the United States (Collins, 1945). The peaks correlate very well with current medical reports of the occurrence of epidemics of influenza. The amount of excess corresponds roughly with the extent, duration, and intensity of the outbreak so far as it affected this country. Depending upon the extent of spread in a particular epidemic period, these peaks can be correlated to some extent with excess mortality from pneumonia and influenza occurring in other countries at about the same time. Outbreaks occurring in scattered localities, particularly when characterized by a low

frequency of pneumonic complications, would not produce the excess mortality necessary to become apparent in this figure. This limitation has become particularly evident in recent years with the lowered case fatality from pneumonia due perhaps in part to the use of antibiotics.



Courtesy Selwyn D. Collins, Public Health Service, Washington, D. C.

Fig. 1-5. Excess annual death rates: influenza and pneumonia by weeks: 90 cities, 1918-1943; 56 cities, 1944-1950.

After several years, during which there was apparently a low prevalence of influenza in this country, there were small epidemics in the winter of 1916-1917 and in April, 1918. These were followed by the pandemic, beginning in September and reaching a peak on October 16, 1918, with minor waves lasting until the spring of 1919. There was a considerable outbreak in the following year, 1920. Since that time there have been small outbreaks at irregular intervals up to the present. Virus A was identified in the cases occurring during the epidemics of 1933, 1935, 1937, 1939, 1941 and 1943. There is evidence to suggest that the epidemic of the winter of 1936 was due to virus B and this virus was isolated from cases occurring in the winter of 1940. On the basis of this formulation, the Commission on Acute Respiratory Diseases (1946) postulated that epidemics of influenza A had a periodicity of two to three years and epidemics of influenza B had a periodicity of four to six years. Following this postulation, an outbreak of B, reaching its peak in November and December, 1945, occurred as anticipated. A small outbreak of influenza A occurred in the spring of 1947 and again in the winter of 1949-1950. A longer



period of experience will be needed to assess the validity of this concept of a regular periodicity but it affords a useful hypothesis about which to assemble the facts known about the epidemiology of influenza in a meaningful pattern.

**Epidemiological Features.** Conditions are most favorable to the spread of influenza in the temperate zones during the winter and spring months. Nearly all epidemics reach their peak between November of one year and May of the next. A notable exception is the pandemic of 1918-1919 which began in September and reached its peak in October. Sporadic cases and small outbreaks may, however, occur during any month of the year.

All ages are susceptible to attack. The frequency of attack tends to be slightly higher in childhood but remains at a fairly constant level with a very slow decrease throughout adult life. The highest mortality rates are registered at the extremes of life. In general, case fatality is high under five, quite low throughout childhood and early life, rising rapidly in the older ages after 50. The pandemic of 1918-1919 showed two significant deviations from the general rule. It showed an unusually high incidence in young adult life with a rapid decrease after age 30. More strikingly, the force of mortality fell upon young and middle aged adults between the ages of 15 and 45 years. The important fact, however, is that influenza involves the whole life span. After the first few years of life there is no indication of the accumulation of immunity with advancing age. This is undoubtedly due to the fact that immunity following attack is of relatively short duration; the same individual may be repeatedly attacked after varying intervals of time.

Another characteristic is the rapidity with which influenza spreads. Large geographic areas become involved in a short period of time, so short indeed it seems almost as if there were simultaneous outbreaks in different places. Epidemics tend to be explosive in character. Duration in any one locality is from six to eight weeks. In compact communities, such as camps, an epidemic may run its course in four to six weeks. This rapidity of spread is explained by the short period of incubation, 24 to 72 hours, the large proportion of mild missed ambulatory infections, the relatively high proportion of the population susceptible to attack, and the ease with which the contagion is communicated from one individual to another.

Three factors are of particular importance in explaining the variation in intensity and extent of different epidemics. These factors are, respectively, the characteristics of the prevailing virus strain, the current state of susceptibility against this strain, and the amount of crowding and intercommunication in the affected population. With regard to the first factor, there are antigenic differences between strains recovered in different epidemics which have significant immunological implications (Friedewald, 1944; Gordon, 1942; Jordan and Gaylin, 1953). Types A and B are capable of considerable variation both in regard to antigenic structure and to biological properties of infectivity and virulence. Recovery from an attack from one strain of influenza, type A for example, does not completely protect against an attack from another strain of type A which is antigenically different. In regard to the second factor, the current status of susceptibility against the epidemic strain is indicated by low levels of antibody in the sera of the exposed population. The longer the time elapsed since the last experience with a given type, the greater the degree of susceptibility of the population. That such changes actually occur has been

demonstrated by several investigators. This is illustrated by the accompanying table taken from the study of influenza A at Fort Bragg in 1943, which shows a comparison of the pre- and postepidemic levels of antibody in the sera of 588 individuals. The third factor, i.e., the effect of crowding and intermixing among people

Table 1-4. Correlation between pre- and postepidemic titers of antibodies to influenza A

Pre-epidemic Titers	Postepidemic Titers								Total
	16	16-31	32-63	64-127	128-255	256-511	512-1027	1028 +	
16	6	9	5	4	1	1			26
16-31	6	71	48	32	23	10	3	3	196
32-63		15	124	45	31	14	8	2	239
64-127			12	65	17	9	2	3	108
128-255				3	14	1			18
256-511									
512 +							1		1
Totals	12	95	189	149	86	35	14	8	588

From Comm. on Acute Resp. Dis., Studies of 1943 epidemic of influenza A. VII, Am. J. Hyg., 48:329, 1943.

has had repeated demonstrations. The highest attack rates from influenza are experienced in closed populations, such as in institutions, on board ships, among troops on board trains, and among troops quarantined in military barracks. On the contrary, among people living in rural areas with good housing conditions and relatively infrequent personal contacts the attack rate tends to be lower and the duration of the epidemic more protracted.

**Survival Between Epidemics.** The mechanisms responsible for the survival of influenza virus between epidemics has been a matter of speculation for many years. Two principal theories have been advanced. One is that influenza viruses have an existence in extrahuman reservoirs from which they emerge from time to time as conditions become favorable. This theory received support from Shope's interesting study of the mechanism of survival of swine influenza (Shope, 1941) which involved the lung worm and the symbiotic activities of *Hemophilus influenzae suis*. Although the virus of swine influenza is probably a variant or mutant of the human virus type A, the relationship between the swine disease and the human disease has not been established. No other extrahuman reservoir of type A, B or C influenza virus has been discovered. The second theory advanced is one of survival in the human host. According to this hypothesis, the influenza viruses propagate by continuous transfer from one human being to another, much as measles does between epidemics. If this were true, it should be possible to demonstrate sporadic cases in small outbreaks of influenza in nonepidemic periods. With this question in mind, the Commission on Acute Respiratory Diseases (1948b) conducted an intensive search for cases of influenza in the flow of a military population of a large Army post for a period of nearly three and one-half years. Serological examinations were made upon 2,932 patients admitted to the respiratory disease wards of the station hospital. During this period both influenza A and influenza B occurred sporadically as well as in epidemic form. Sporadic cases of influenza cannot be differentiated clinically



from cases of the common cold and other acute respiratory diseases. Sooner or later with the appearance of a new variant strain, with the accumulation of susceptibles in the population, or with the development of other favorable conditions the endemic prevalence is translated into an epidemic spread.

**Vaccination.** Early in the study of influenza viruses Francis and Magill showed that mice could be actively immunized against intranasal inoculation by means of subcutaneous or intraperitoneal injection of active mouse-lung or ferret-lung PR8 virus, thus establishing the principle that active resistance to experimental infection could be accomplished. The demonstration that influenza virus could be grown on the chorio-allantoic membrane of embryonated hen's eggs made available a practical method for production of large quantities of virus. Studies on vaccination of man against influenza were initiated in 1936, and pursued intensively by several investigators. Different preparations of both active and formalin-inactivated virus were employed. While these vaccines stimulated some rise in antibodies in vaccinated individuals, there was no acceptable evidence that they induced a sufficient degree of resistance to natural infection to warrant their use on a wide scale (Horsfall, 1940).

Francis (1939a) showed that within certain limits a direct proportional relationship existed between the concentration of virus used for immunization of mice and the degree of active immunity to intranasal infection induced. This suggested that a more concentrated vaccine than those being tried would be necessary to produce an effective immunity in man. Taking advantage of the observations of Hirst and others that influenza virus in the chorio-allantoic fluid of the infected chick embryo could be directly absorbed by the red blood cells of the embryo and that the absorbed virus can be readily eluted from these cells at 22° to 37° C, Francis and Salk in 1942 devised a simple procedure for producing a purified and more concentrated vaccine. By this method approximately tenfold concentrations of both PR8 and Lee strains were obtained consistently. This made possible the production of a potent mixed vaccine containing the PR8 and Weiss strains of A virus and the Lee strain of B virus which was suitable for large scale human trial to test the protective value under conditions of experimental and natural exposure. The results of these trials have been reviewed by Blake (1948).

In two adequately controlled experiments a considerable degree of success was obtained in vaccination against influenza A in the epidemic of November-December, 1943, and the influenza B epidemic in the fall of 1945. However, in another trial during the epidemic of influenza A in 1947, there appeared to be little or no protection of the vaccinated as compared to the unvaccinated groups. Subsequent studies showed that, while the vaccine produced antibodies against the PR8 and Weiss strains, it did not produce satisfactory level of antibodies against the 1947 epidemic strain, which received the designation "A prime." Each cubic centimeter of commercial vaccine available in 1952 contained Type A (PR8), Type A' (Cuppel, FMI) and Type B (Lee) strains. The adult immunizing dose is a single 1.0 cc. by subcutaneous or intramuscular injection. For children under 12 years, the dose should not exceed 0.5 cc., with proportionally less for the very young because of the apparently greater toxicity in this group. Persons sensitive to eggs, chicken or chicken feathers should not be vaccinated.

Salk (1953) obtained promising results experimentally by emulsifying influenza vaccine in mineral oil of low viscosity. The addition of this adjuvant increases the antibody response in titer and duration and gives broader antigenic coverage to include strains related but not identical to those in the vaccine. Many important practical questions require study and solution before an effective vaccine is at hand.

From the data available it would appear that a considerable degree of immunity would persist in the population group one year after vaccination. Annual repetition of vaccination would probably be required to maintain protection. It should be done prior to the appearance of an epidemic, because it requires at least a week to establish immunity and epidemics ordinarily spread so rapidly that it is impractical to undertake mass vaccination with the expectation that it can be carried through before the epidemic has reached its peak in any given community. Furthermore, the best method of vaccination and the best type of vaccine with respect to antigenic content, dosage, and method of injection remains to be determined. For these reasons vaccination against influenza must still be regarded as in the developmental stage.

**Control Measures.** The problems of preventing the spread of influenza are similar to those of other respiratory infections. The possibilities are considered in another chapter. On account of the widespread and rapid distribution of infections in a community, the large proportion of infections which are mild and ambulatory, and the fact that it is contagious in the earliest stages, measures of isolation and quarantine are of little value. In isolated population groups and in institutions infection has been delayed and sometimes avoided by strict exclusion of all visitors. During an epidemic it is advisable so far as is practical to urge voluntary reduction in activities which bring people into common assemblies. The attempt to prevent crowding by official regulations requiring the closing of schools, theaters and other places of public assembly is not advisable. Quarantine measures which interfere with the normal activities of a community are ineffective and not justifiable. The administration of influenza vaccine to large groups of people may be justified under some circumstances, but is subject to the limitations previously outlined.

During an epidemic the principal public health administrative effort should be directed toward providing good medical care to those who are ill enough to require it with a view to preventing complications and death. To minimize the severity of the disease and to reduce the risk of secondary infection persons becoming ill should be urged to go to bed at once and remain there during the febrile stage. Patients should have the advantage of appropriate chemotherapy if indicated for treatment of complicating bacterial pneumonia. On account of the risk of secondary infection hospitalization is to be avoided, particularly if crowded conditions exist and personnel and facilities are insufficient to care adequately for patients.

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## PNEUMONIA AND PNEUMOCOCCAL INFECTION

The term "pneumonia" includes a group of varied diseases due to different causes, but all producing an inflammation in the lung tissue. Pneumonia may be primary or secondary; it may be lobar (croupous) in type or it may be lobular (bronchopneumonia); it may be due to bacteria, to fungi, to rickettsia, or to viruses. Classifications according to the anatomic pictures and the causative agents do not run parallel, but the latter are more significant from the standpoint of prevention and cure.

While the pneumococcus is the most common cause of pneumonia, pathogenic bacteria of other species and genera may be responsible, such as streptococci, Pfeiffer's bacilli, Friedländer's bacilli, plague bacilli, and typhoid bacilli. A pneumonic condition is also a frequent terminal state especially in the young and in the old. Because of the difficulties of classification, changing concepts of etiology and different standards of diagnosis, there is much confusion in the literature as well as in the morbidity and mortality records concerning pneumonia. A common error is to report death as due to pneumonia when the pneumonia is only a terminal event.

Lobar pneumonia is a clear-cut variety of the group clinically and histologically, and studies have shown that the pneumococcus is the responsible agent in about 95 per cent of the cases. This is an acute febrile infection with massive consolidation of lung tissue which, in typical cases, ends by crisis. The pneumococcus is found not only in the lungs and the respiratory tract but often invades the blood—an index of the severity of the infection. Pneumococci are also frequently found to be the cause of bronchopneumonias and secondary pneumonias complicating operations, trauma, and other conditions.

**Mortality from Pneumonia.** In 1900, pneumonia and influenza were the leading causes of death in the U. S. Registration Area. Death rates from these causes declined from 202 per 100,000 population to 38.2 in 1948. Referring to Figure 1-5, the decline was interrupted by epidemic rises associated with a series of epidemic waves of influenza, the greatest occurring from 1916 to 1920 associated with disturbances of World War I and the pandemic of 1918. With these exceptions, the general level of mortality from pneumonia and influenza remained about the same up to about 1937. Deaths from bronchopneumonia followed much the same trend, and deaths from lobar pneumonia had a similar configuration up to 1937. From that point on, interrupted only by the influenza outbreak in 1943, the decrease is more rapid for lobar than for bronchopneumonia. While this decline may be due in part to more accurate classification of deaths from specific causes, it would seem reasonable to suppose that the use of highly effective sulfonamides and antibiotics in specific treatment of pneumococcus pneumonias has been an extremely important factor (Chandler and others, 1949). The decrease in cases of lobar pneumonia



admitted to hospitals has been one of the most remarkable phenomena in the infectious disease pattern of the last few years.

**Typing of Pneumococcal Infections.** The fact that pneumococci can be classified into specific types which vary in their potential pathogenicity has been valuable not only in identifying the causative agent in cases of pneumonia but also in tracing the distribution of these organisms among persons suffering from subclinical or inapparent infection. A preliminary examination of suspected material, such as blood, sputum, pus, exudates in preparations stained by Gram's method, usually gives important information with regard to the nature of the infective agent. The ovoid or lancet-shaped cocci in pairs or in chains surrounded by capsular material affords a lead to identifying procedures. Growth is easily accomplished by means of nutrient broths or agar to which serum or defibrinated blood has been added. After 18 to 24 hours of incubation on blood agar plates, the colonies have a characteristic appearance. As in the case of other bacteria, the pneumococcus undergoes smooth to rough variation. The smooth colony type is characteristic of encapsulated type specific and fully virulent pneumococci. Rough colonies are associated with a loss of ability to produce capsules. The smooth to rough variation tends to occur in cultures maintained for long periods of time on artificial media. Reversal, rough to smooth variation, may be brought about by animal passage or cultivation of rough strains in the presence of antirough immune serum, heat-killed encapsulated cells, or extracts thereof.

Studies of the chemistry of the pneumococcus cell by Avery, Dochez, Heidelberg, MacLeod and others have contributed very greatly to an understanding of the fundamentals of immunology. The cell substance itself appears to be the same in all pneumococcus types. It is composed of proteins, nucleic acid, lipoidal materials and carbohydrates. The capsular material, known as a specific soluble substance (SSS), is a complex carbohydrate or polysaccharide. The immunologic differentiation of pneumococci into types is dependent upon the elaboration of SSS during growth. The production of these polysaccharides is essential to the pathogenicity of pneumococci and bears a direct relationship to virulence (MacLeod and Krauss, 1950). The antibodies which protect man and animals against infection neutralize the activity of this material.

Classification of the pneumococci into types began with the work of Neufeld and Handel in Germany in 1909 and 1910, who showed that there were definite serological differences between certain pneumococcal strains. Dochez and Gillespie (1913) were able by protection and agglutination tests to subdivide pneumococci into four groups: Type 1, Type 2, Type 3 and Group 4, or miscellaneous group. Cooper and her associates (1932) identified or reclassified 29 types which were previously considered together as Group 4. However, recent studies recognize a total of 75 antigenically different types. Certain of these types are much more important and much more widely distributed than are others.

The importance of mouse inoculation as a means of isolating pneumococci when present in small numbers, and particularly when mixed with other organisms of the common respiratory flora, is well recognized. Cultures can be typed by agglutinins or precipitin reactions with type-specific antisera. The Neufeld method of typing has also made possible the identification of pneumococcus types directly from sputum

or other infected materials and from cultures even when the organisms are present in relatively small numbers and in the presence of numerous other bacteria.

**Distribution of *Pneumococcus* Types.** The development of simple procedures for the typing of pneumococci led to studies by many investigators in various parts of the world of the frequency of different types in cases of lobar pneumonia and bronchopneumonia and in well persons associated with cases or in the general population (Heffron, 1939). From these studies, certain generalizations have been derived which are of value in understanding the occurrence of pneumonia in human populations.

Pneumococci are part of the constantly changing flora of the upper respiratory tract of man. The frequency with which various types are found varies with geography, season, age, sex, and other conditions. While all of the 75 or more types are potentially capable of causing infection, some of them are much more commonly associated with pathology than others. Type 1 and Type 2 organisms are intimately associated with primary lobar pneumonia and are found almost exclusively in relation to this disease. Type 3, although next in importance, is more widely distributed in normal throats and associated particularly with the pneumonia of old age. In the United States, these three types have been responsible for from 50 to 80 per cent of the cases of lobar pneumonia in adults, the remainder being due to Types 4, 5, 7, 8 and occasionally others. In the bronchopneumonia of adults the type distribution is similar to that found in well persons. In children below the age of 12, Types 14, 1, 6, 5, 7 and 19 have caused more than half the cases of pneumonia.

**Carriers.** The same specific type may persist and be recovered from the throat of a convalescent for only a few days or, in some cases, for several months; occasionally for more than two years. In some of the patients who remain carriers for a long time, pneumonia of the same type may recur.

About one half to one fourth of normal persons having no contact with pneumonia have been found to carry pneumococci at any given time. Webster and Hughes (1931) classified healthy individuals into four categories with respect to the finding of pneumococci in cultures from their nose and throat, namely, those who are free from pneumococci, the transients, the periodic and the permanent carriers. The same type or types may be found repeatedly in some persons, while in others they appear intermittently, and in still others different types appear and replace the earlier ones which are no longer found in subsequent cultures. Almost every person can be shown to carry pneumococci in the nasopharynx at one time or another if cultures are taken repeatedly. They are frequently recovered from infants after the first few months of life. Seasonal fluctuations in the incidence of pneumococci carriers correspond to fluctuations in the incidence of cases. Among family contacts of cases of pneumonia there is almost always a very high incidence of carriers of the same type of pneumococci that are found in the cases.

**Immunology.** Studies of the distribution of pneumococci in well persons have indicated that resistance against these organisms, both natural and acquired, is sufficient in most individuals most of the time to protect against clinical attacks. It has been estimated that ordinarily not more than one out of 500 persons harboring pneumococci in the course of a year develops pneumonia. One attack of pneumonia does not necessarily confer high or lasting immunity. Recurrence is more common



than in any other acute disease. The recurrence may be due to the same type or to different types.

Immunity is in part due to humoral antibodies and to a considerable degree type specific. The existence of this immunity can be demonstrated by various methods. Thus, fresh defibrinated blood of most humans has some bactericidal power against many types of pneumococci. This property may, in some individuals, vary qualitatively and quantitatively for different types of pneumococci. For each type, however, pneumococidal powers are present in the blood of infants during the first few days after birth with about the same frequency as in adults. Each infant resembles its mother in this respect. This pneumococidal power is apparently lost by the end of the first month and cannot be demonstrated again until after the first year. It is less frequent in children than in adults and declines again after 60 years of age. Blake (1932) found nontype-specific agglutinins in human serum. The curve of incidence of such agglutinins in the various age groups seemed to mirror the morbidity rates for pneumonia in the same community; that is, the morbidity was highest in the age groups in which the least agglutinins were found, and vice versa. Felton (1940) demonstrated mouse protection antibodies against one or more lethal doses of Types 1 and 2 pneumococci in the serum of almost one third of some 1,100 human subjects. Immediate positive skin reactions to type-specific polysaccharides (Francis, 1933) can be used to indicate the presence or absence of circulating antibody.

Studies made with these methods have indicated that the amount and types of circulating antibodies vary in individuals from time to time and from place to place. By analogy with other infections, it is reasonable to suppose that the pattern is determined by specific antigenic stimuli and experience with a pneumococcus infection, either clinically manifest or inapparent.

**Specific Serum Therapy.** Studies of the disease in experimental animals and man have led to the conclusion that if circulating antibodies are increased above a critical level, recovery from pneumonia usually follows. With a view to conferring passive immunity upon patients sick with the disease specific antisera were developed. Applied originally to treatment of pneumonia caused by Types 1 and 2, highly potent antisera later became available commercially for pneumonia caused by a majority of pneumococcal types. The early standard sera were prepared by the immunization of horses. Later, it was found that higher titers of antibody could be obtained by the use of rabbits. Dosage of antiserum was adjusted so that an excess of antibody was constantly present in the blood. As early as possible in the course of the disease serum was administered intravenously in an amount sufficient to result in a positive polysaccharide skin test. In most instances, defervescence and the onset of recovery occurred within a few hours after sufficient antibody had been given. Much was learned about the immunology of pneumonia from the use of specific serum therapy. However, in 1937, sulfa drugs were introduced and these, together with antibiotics, have proved to be so simple and effective in treatment that serum therapy has been given up.

**Nonspecific Factors in Resistance.** Before pneumococci can begin to multiply in lung tissue they must make effective contact with a cellular area in which conditions are favorable for growth. This involves passage through spaces in the upper respiratory tract of clumps of virulent pneumococci, usually in air-borne droplet nuclei or dust of particle size appropriate to reach the trachea, bronchi, or possibly

the terminal bronchioles. The first barrier in defense is the mucus secretion kept in motion by the ciliary action of the cells lining the respiratory mucous membranes and the associated reflex clearing mechanism. If this fails and pneumococci find lodgement in the lung tissues their immediate fate is determined by the numbers and

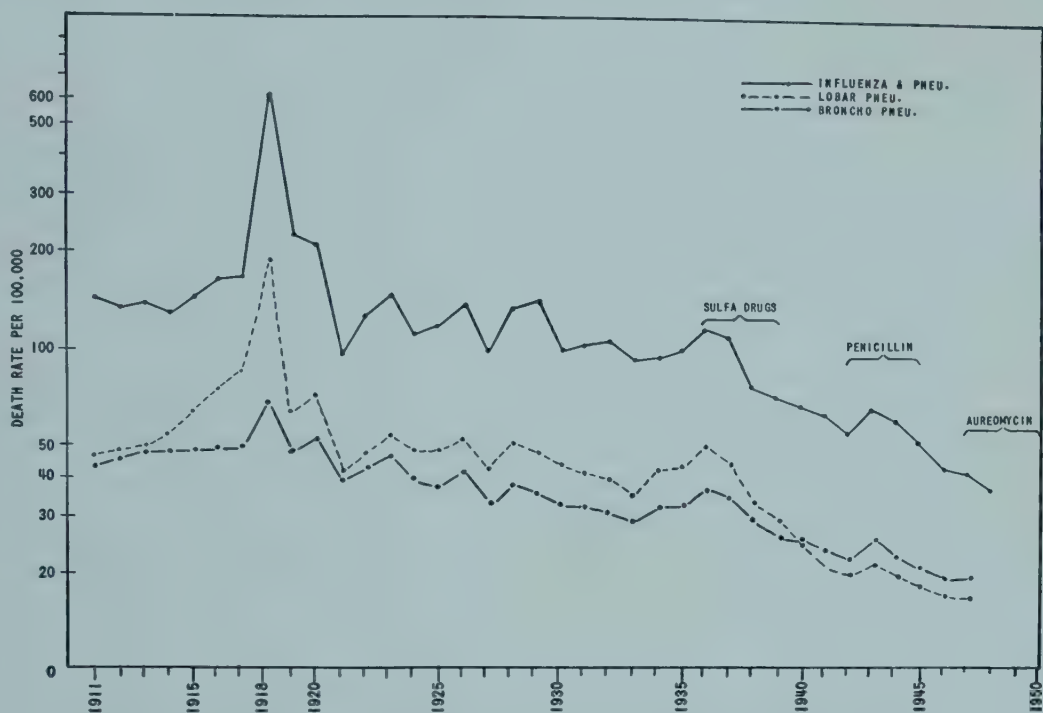


Fig. 1-6. Mortality rates per 100,000 population, United States, for pneumonia and influenza, lobar pneumonia and bronchopneumonia.

activity of the phagocytes in the neighborhood. From this point the humoral antibody begins to determine the issue. The total defense mechanism is only imperfectly understood, but evidently it is nicely balanced and easily disturbed by a number of conditions.

It is apparently less efficient in infants and old people and persons who are debilitated for various reasons. Pneumonia often closes the scene in chronic heart disease, pulmonary phthisis, Bright's disease, diabetes and other debilitating affections. Osler said: "Pneumonia may well be called the friend of the aged. Taken off by it in an acute, short, not often painful illness, the old escape those 'cold gradations of decay' that make the last stage of all so distressing."

Conditions favorable to the development of pneumococcus pneumonia result from the pathologic changes precipitated by influenza, measles, whooping cough, and other acute infections. Pneumonia may follow operations in which a general anesthetic has been administered, acute or chronic alcoholism, severe trauma, inhalation of irritant dusts and gases and, in general, conditions which may damage lung tissue and favor aspiration of micro-organisms.

While it seems likely that pneumococci of considerable virulence are essential to the production of pneumonia in lobar form, the evidence at hand also suggests that in the presence of such organisms the disease occurs in the usual instance as a result of temporary lowering of host resistance. Many investigators have called



attention to this matter and have stressed the importance of various factors, the most often mentioned are: acute minor respiratory infections, or other infectious diseases, exposure to temperature variations, chilling, wetting, and fatigue. Nevertheless, the fact remains that a considerable proportion of the cases of lobar pneumonia occur in healthy, robust individuals without apparent association with predisposing conditions.

**Mode of Transmission.** Spontaneous outbreaks of pneumococcal infections occasionally occur among animal stocks, particularly among guinea pigs and monkeys, when kept under artificial conditions. However, there is no reason to believe that there exists an extrahuman reservoir of any consequence. Pneumococci are primarily adapted to survival in the human race. The sources of pneumococcal infections are: cases, convalescents, and carriers, the last named being far more numerous than the others. As with other respiratory diseases, transmission from one individual to another is effected by means of talking, coughing, sneezing and contamination of articles or food by respiratory secretions. The relative importance of direct or indirect routes is unknown and probably varies with circumstances. The organism is comparatively frail, does not multiply in nature outside the body and is easily killed by sunlight and drying. It may survive for a period of time, usually a matter of hours, protected by mucoid secretions on contaminated objects and in floor dust. It is readily destroyed by heat; 52° C at 10 minutes is sufficient. On the other hand, it withstands low temperatures very well. The ordinary germicidal agents destroy it quickly and with certainty.

**Ordinary Occurrence.** Under ordinary circumstances, pneumococcus pneumonia occurs as a sporadic disease. The cases are scattered as to place, time, and persons. There is little tendency to focal concentration, although incidence bears a relation to density of population. In temperate zones, pneumonia shows a marked seasonal variation similar to that of the other respiratory diseases. Maximum prevalence is reached during the coldest months of the year. This is reasonably attributed to seasonal changes in the habits of living which bring people into closer contact indoors, thus favoring the exchange of respiratory micro-organisms. It is possible also that during these periods nonspecific factors depressing host resistance may be more generally operative than in the warmer months of the year. Otherwise, climate has no great influence on the distribution of pneumonia.

Inadequacies of reporting of pneumonia make it impossible to determine the exact incidence of the disease in persons of various age groups. Direct evidence concerning this matter comes frequently from the reports of hospitals and allied institutions, which at best give little more than an index of the relative frequency of pneumonia in any age group. It seems to be generally true, however, that pneumonia may occur at any period of life but the incidence is highest in the young and the old. Death rates both from lobar and bronchopneumonia are high under five years of age, relatively low throughout childhood and young adult life, increasing, at first gradually and then rapidly, with advancing years after 50. Most of the available data support the concept that pneumonia, and especially lobar pneumonia, is more frequent in males than in females. From many reports it appears that compared with white people living and working in the same district, Negroes have a higher morbidity and mortality rate for pneumonia. However, in these accounts it is not possible to discount differences in immunity acquired through previous experi-

ence of the racial groups. The frequency of pneumonia among African Negroes in the gold and diamond mines in the vicinity of Johannesburg, Pretoria, and Kimberley in the more temperate zones of South Africa, has been the subject of extensive investigation. The immunity of the natives appears to increase markedly after the elapse of a few months of time in the new environment. It seems probable that the unusual severity of pneumonia among the recent arrivals is due, not so much to fundamental differences in race, but to the fact that such natives had had little experience or exposure to the prevalent pneumococcus types and consequently have little initial effective resistance against these organisms. Marked overcrowding, usually associated with low economic status, undoubtedly favors the transmission of pneumococci and tends to increase the incidence of pneumonia. Persons engaged in certain occupations, especially those requiring fatiguing labor out of doors in all kinds of weather, those who experience intimate exposure to intense heat, and those exposed to some forms of dust have higher pneumonia morbidity and mortality rates, or both, than others not so employed. This also appears to be true in underground miners who may be exposed to considerable change in temperature during the course of their work and upon their return to the surface. The increased risk is not associated with the execution of the precise occupation so much as it is with the collateral conditions which may lower resistance to pneumococcal infection.

In summary, the principal factors controlling the prevalence of pneumonia under ordinary conditions seem to be (a) the nature of the infective organism, (b) the opportunity for acquiring the infection, (c) the nature of the predisposing factors to which the individual is exposed, and (d) the host and his resistance.

**Epidemic Occurrence.** There are many accounts of epidemics of pneumococcal pneumonia (Finland, 1942). These may be classified under two headings. The first is excessive prevalence of pneumococcal pneumonia in a population over a considerable period of time due to several types of pneumococci. Under the second are included sharp outbreaks which occur in inmates and personnel of hospitals for chronic mental diseases, in children's homes, orphanages and other institutions, in which a single type of pneumococcus is responsible for an unusual number of cases of pneumonia in a short period of time. A good example of the former is an epidemic of pneumococcal pneumonia which occurred among the personnel of an Army Air Force Technical Training School, over a two and one-half year period during World War II, investigated by Hodges and his colleagues (1946). In the population flowing through this station in that period of time there were 1,600 cases of pneumonia. *Pneumococcus* Type 2 was the predominant organism over the entire period, causing approximately 35 per cent of all cases of pneumonia. Types 1, 5, 7, 12 and 4 were responsible for large numbers of infections and were considered also as epidemic types.

From the data collected no simple explanation of the extremely high pneumonia rates encountered in the technical school could be offered. The high incidence appeared to have been the result of a number of factors. At the beginning of the epidemic, in the winter of 1942-1943, high carrier rates for the infective types were built up in the personnel of the school. Under conditions of crowding and dusty classrooms and barracks, and an unusual prevalence of undifferentiated respiratory disease, widespread transmission of these micro-organisms was facilitated. Propagation was maintained by the intermittent arrival and departure of classes in the train-



ing courses. There was a thorough mingling of the new relatively susceptible arrivals with the permanent party personnel and those held over from previous contingents. Among those who had their first experience with an infective type there were always a few who had an inadequate defense mechanism and came down with pneumonia.

Similar but less complicated situations are described in the reports dealing with outbreaks of single types (Strom, 1932; Smillie, 1936; Smillie and others, 1938; Gilman and Anderson, 1938; Stebbins and others, 1940). In these, it was more clearly evident that a highly virulent Type 1 or Type 2 pneumococcus had been introduced into a susceptible population under conditions which favored spread by carriers and person-to-person contact.

**Prophylactic Vaccine.** It has long been known that experimental animals may be rendered actively immune to pneumococcus infection by previous injection of nonlethal doses of pneumococci or even by the injection of dead cocci. Frequent attempts have been made to immunize man against pneumococcal pneumonia with various antigenic preparations within the past 35 years (Heffron, 1939). In the earlier trials the vaccines consisted of heat-killed pneumococci which were injected subcutaneously. Almost all investigators concluded that the procedure exerted a beneficial effect. The validity of these conclusions, however, can be questioned because of the variables which clouded interpretation, such as differences in the composition of the immunized group and control groups, uncertainty as to whether the specific pneumococcal types included in the immunizing preparation were the same as those currently causing pneumonia, failure to determine whether the observed decline in cases in the immunized group was due to a decrease in cases caused by pneumococcal types included in the vaccine, and inadequate control of the antigenicity of the preparation used. In more recent years preparations of capsular polysaccharides have been used following demonstration by Francis and Tillett in 1930 that the isolated polysaccharides are antigenic for man. Suggestive evidence was obtained, especially through the studies of Felton (Ekwurzel and others, 1938), that the immunization of man with capsular polysaccharides will prevent pneumococcal pneumonia. This evidence has been recently extended and more convincingly demonstrated by MacLeod and others (1945). In a carefully controlled human trial under military conditions they found that immunization of man with 0.03 to 0.06 mg. of each of the capsular polysaccharides of pneumococcus Types 1, 2, 5 and 7 given in a single subcutaneous injection was shown to be effective in preventing pneumonia caused by these types and not that due to heterologous types. The immunity appears within a period of two weeks following the injection of the polysaccharides. The duration has not been determined, although six months can be set as a minimum. The carrier rates of pneumococcus Types 1, 2, 5 and 7 were lowered significantly in the immunized group as compared to the controls. It was suggested that overall reduction in the incidence of carriers was responsible for the lowered rates in pneumococcal pneumonia in the nonimmunized group.

It has thus been demonstrated that under special conditions immunization with capsular polysaccharides can provide an artificial immunity of sufficient degree to decrease the carrier rate and lower the incidence of pneumonia. It is to be noted, however, that this can only be accomplished where the polysaccharides used in the vaccine are of the same type as the prevalent infecting organisms. With present knowledge it is not practical to produce a vaccine effective against all types. The

procedure, therefore, is still in the stage of experimental development, and applicable only to selected situations.

**Preventive Measures.** The prevention of pneumonia secondary to other acute infections and debilitating conditions is a matter of prevention and medical care directed toward the primary cause. The prevention of primary pneumococcal pneumonia should be considered both from the point of view of reducing morbidity and of reducing mortality. The problems associated with reducing the prevalence and spread of pneumococci in human populations is involved in the larger problem of control of respiratory disease in general which is considered in a separate chapter.

Precautions to prevent spread from a case of pneumonia to immediate contacts are in order. Isolation of the patients with aseptic nursing technic is desirable. Particular care should be taken in the disposal of discharges from the nose and throat of the patient, and handling of bedclothes, linens, blankets, and utensils contaminated therewith. Quarantine of familial contacts or close associates is not practical or justified. Upon the death or discharge of a patient thorough cleaning and airing of the room is sufficient, bearing in mind the danger from floor dust.

Occupational hazards created by working conditions, such as exposure to marked variations in temperature, wetting, chilling, irritating dusts, as well as the performing of strenuous, fatiguing labor out of doors in inclement weather, and other provoking factors can be reduced by appropriate attention to industrial hygiene.

To control outbreaks in dormitories, barracks, hospitals, asylums, labor compounds, prisons, and the like, procedures directed toward the discovery and isolation of carriers of the infective types of pneumococci are usually not practical. Under special conditions it may be worth while to search for dangerous chronic carriers (see material on streptococcus infections, page 80). Every effort should be made to reduce crowding in sleeping, living, recreational, and working quarters. Special attention should be given to housekeeping arrangements, removal of dust, and cleanliness of floors and surfaces. All cases of incipient respiratory disease with fever and constitutional symptoms should be promptly isolated in bed pending diagnosis. Appropriate chemotherapeutic or antibiotic treatment will shorten the period of infectivity and reduce the risk of spread of bacterial infection. It will, in like manner, reduce the risk of a fatal issue.

**Treatment.** Penicillin intramuscularly or oral penicillin G are usually effective in treatment. In the event of penicillin sensitivity or delayed response tetracycline antibiotics are substituted. Sulfonamide drugs and erythromycin are also effective.

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## SCARLET FEVER AND HEMOLYTIC STREPTOCOCCAL INFECTIONS

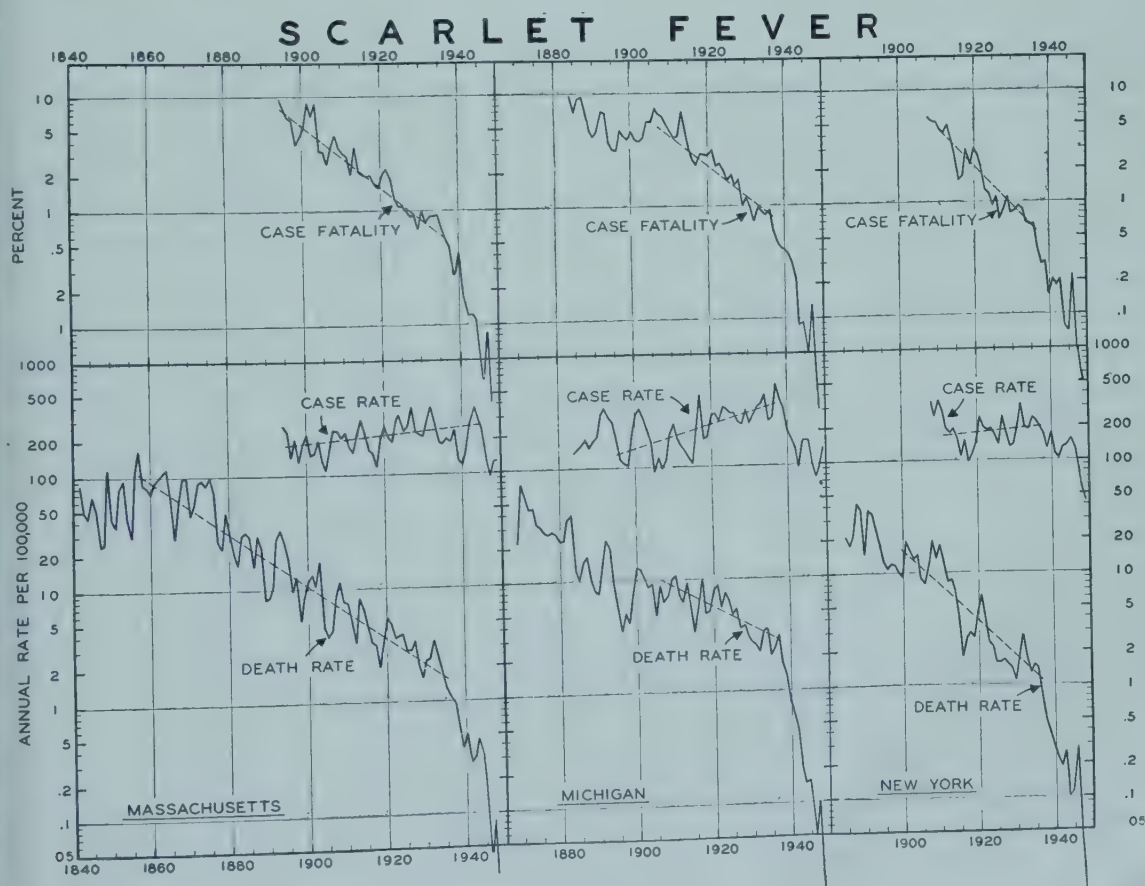
In 1653, Sydenham differentiated the syndrome of scarlet fever, largely on the basis of the characteristics of the skin eruption, from measles and smallpox but this was not generally accepted until the middle of the eighteenth century. Because of the inflammatory process in the throat, which so often occurs in scarlatina, it was confused with *angina maligna* or diphtheritic sore throat until the French clinician Bretonneau pointed out the reasons for regarding diphtheria as a specific disease in 1826. It was well along toward the end of the nineteenth century, however, before these two diseases were distinguished in medical reports and statistics.

The syndrome of scarlet fever was recognized as acute infection, characterized by sudden onset, with fever, sore throat, and a rash followed by desquamation. The fever lasts about four days and declines by lysis. The rash is a generalized punctate erythema which usually appears within 48 hours, starting about the neck and spreading downward; the exanthem is visible on the mucous membrane of the palate and surrounding parts. The cheeks are flushed and the area about the mouth presents a dead-white pinched appearance (circumoral pallor) which is striking and characteristic. Vomiting often ushers in the disease and the strawberry tongue follows. The disease varies greatly in severity; mild and missed cases and carriers are common and spread the infection.

Clinically, either the toxic or the septic manifestations of scarlet fever predominate. The toxic type is characterized by prostration, fever, rash, and a red throat; the septic type, by tonsillitis, adenitis, sinusitis, otitis, and sometimes mastoiditis and septicemia. In a small proportion of cases evidence of nephritis appears about the third week. Occasionally rheumatic manifestations—arthritis and synovitis—develop during late convalescence.

**Trend of Scarlet Fever.** To Thomas Sydenham, "febris scarlatina" was a mild disease. By the end of the eighteenth century, a severe form was prevalent in England, for in Willan's reports on diseases in London in the years from 1796 to 1800, there are numerous references to the gravity of scarlet fever at that time. Immediately after this period the severity diminished. Bateman, writing of the disease in London in the years 1804 to 1816, frequently alludes to the mild type of scarlet fever. There is no question that a change occurred after 1830 and the disease became, as Creighton noted, "the leading cause of death among the infectious diseases of childhood." Apparently it remained so in England and in this country until the middle of the nineteenth century.

Pope in 1926, using Chapin's material, reviewed the experience of Providence, R. I., in regard to scarlet fever in the years from 1865 to 1924. The death rate of children of ages two to four had decreased in this interval from 691 to 28 per 100,000 (or to about one twenty-fifth of the rate of 70 years ago), but the attack rate had not presented a corresponding decrease. The decrease in the number of deaths could not be attributed to a lower average prevalence nor to any changes in the population, but must have been due to the lessened severity of the disease. From 1886 to 1888, one in every five cases died, while from 1923 to 1924, only one of every 114 cases ended fatally. Woods in 1933 showed that a similar change has occurred in England and Wales.



From Collins, S. D., Pub. Health Rep., 61:203, 1946.

Fig. 1-7. Trend of scarlet fever incidence, mortality, and case fatality in three states during 40 to 100 years ending in 1944 for deaths and 1945 (provisional) for cases.



The trend of scarlet fever incidence, mortality, and case fatality based upon official data from Massachusetts, Michigan, and New York is shown in Figure 1-7 (Collins, 1946). There was little change up to 1941 in the incidence of the disease as indicated by the rates based on reported cases. The case fatality rates continued to decrease up to 1937. This has been attributed to a change in virulence of the prevailing strains of the causative organisms, but perhaps to some extent indicates improvement in medical care. The accelerated decline which came in the late thirties coincides with the increased use of the sulfonamides and antibiotics in the treatment of scarlet fever and its complications.

These observations could be amplified and corroborated by a review of other reports, but the general facts are well established and appreciated. Although the decrease in case fatality rate has been more rapid in some areas than in others, perhaps more marked in southern than in northern climes, and more apparent during the endemic than during epidemic prevalence, it has become general throughout Europe and America. From a fearful and highly fatal malady, scarlet fever has become relatively mild and, in the vast majority of instances, an innocuous ailment.

**Pathogenesis of Scarlet Fever.** With the advent of the bacteriologic era it was confidently expected that the disease "scarlet fever" would be found to be due to a specific microbial incitant, just as were diphtheria, typhoid, tuberculosis, and other common infectious diseases. After 50 years of research, the true nature of the pathogenesis of the disease syndrome has finally become apparent.

The etiologic relationship of streptococci was suspected very early, but attempts to separate those types which were capable of causing scarlet fever from those which were not, by means of cultural and serologic procedure, were only partially successful. It became evident that they belonged to the "hemolytic" streptococci and that they possessed some degree of antigenic relationship. The nature of the essential biologic activity which distinguished them remained undiscovered until some 25 years ago.

At this time, as a result of the observation and experiments of Schultz and Charlton, Mair, Dochez, and the Dicks (1938), it appeared that the peculiar biologic activity which distinguished the hemolytic streptococci which caused scarlet fever was their ability to produce a particular toxin, called Dick toxin, or, more properly, erythrogenic toxin, erythrotoxin, or simply rash-producing toxin. It was demonstrated that the injection of bacteria-free filtrates of broth cultures of hemolytic streptococci containing this erythrogenic toxin into susceptible human beings reproduced cardinal symptoms of scarlet fever, except the sore throat; namely, fever, malaise, nausea, vomiting, and a generalized scarlet rash. This afforded a rational interpretation of the pathogenesis. The sore throat is due to the primary localization of a strain of hemolytic streptococci in the throat with the resulting inflammatory reaction. The characteristic constitutional reaction is due to the toxic products peculiar to these organisms. The complications and ultimate outcome are determined by the ability of the organism to proliferate locally and to invade the tissues progressively. Resistance and recovery depend upon the development of at least two types of immunity: (a) ability to prevent the growth and progressive invasion of the tissues, that is, "antibacterial immunity"; and (b) ability to neutralize the toxic products, especially the erythrogenic toxin, that is, "antitoxic immu-

nity." To what extent the latter affects the former is not yet clear. This conception of the pathogenesis of scarlet fever has now received general acceptance.

**Identification of Scarlet Fever Streptococci.** The question of the specificity of the scarlet fever streptococci is but a small part of the larger problem of the classification of streptococci in general and the correlation of types or subdivisions with the various conditions of health and disease in which they are found in man and animals. The status of knowledge was admirably reviewed by Sherman (1937). Attention here will be limited to those streptococci which produce characteristic beta-type hemolysis in blood agar.

The significant biologic activity which distinguished the hemolytic streptococci recovered from cases of scarlet fever was their ability to produce, under specified conditions of culture, the characteristic erythrogenic toxin. Effort was made to use this quality as a means of identification. It became evident, however, that the ability to produce erythrogenic toxin is a function not peculiar to strains of hemolytic streptococci from scarlet fever alone, but possessed not infrequently by non-scarlatinal strains. Neither on the basis of the quantity nor quality of erythrogenic toxin produced can a sharp distinction be made.

Researches upon the serologic identification of hemolytic streptococci, although discouraging for a long time, recently have been proved to be of considerable value. By means of a precipitin reaction, based upon the presence of these organisms of a group specific polysaccharide, the "C" substance, it was found (Lancefield, 1933) that the hemolytic streptococci could be divided into several broad *serologic groups* which correlated significantly with previous knowledge of host relationships and pathogenicity. In particular, nearly all of the strains of hemolytic streptococci which are important in human pathology, fall into one group: *Lancefield's Group A* (Swift, 1948).

Having established this broad group, it was possible to subdivide it into *types* by means of a precipitin test based upon extracts of the type-specific proteins, the "M" and "T" substances contained in streptococci, or by means of agglutination. Independently, Griffith (1934), by means of a slide agglutination, had established 27 types of "*Strep. pyogenes*" and stated that more than 30 such types exist. All but two or three of Griffith's types have been found to belong in Lancefield's Group A. There was thus afforded the basis for the serologic identification of the principal pathogenic hemolytic streptococci and their subdivision into types.

Certain types, 1, 2, 3, 4, 8, 10 (N. Y. 5), 11, 13, 15, 17, and 19 have been found fairly commonly in scarlet fever (Schwentker and others, 1943). It is equally notable that these same types, and those remaining, have been found in non-scarlatinal conditions, such as tonsillitis, septic sore throat, otitis, mastoiditis, septi-cemia, puerperal sepsis, erysipelas, as well as occasionally upon normal human skin and mucous membranes. In other words, *by serologic technic the types of hemolytic streptococci which cause scarlet fever can be identified, but they cannot, by this means alone, be differentiated sharply from the other types in Lancefield's Group A which have been recovered from nonscarlatinal conditions.*

**Erythrogenic Toxin and the Dick Reaction.** One of the most valuable contributions of the Dicks was the development of the skin test which bears their name. The Dick test consists of injecting a small quantity of erythrogenic toxin *into* the skin. The toxin is diluted so that 0.1 ml. contains just enough to produce the typical



reaction; this amount is also called a *skin test dose*. A positive reaction indicates susceptibility and a negative reaction immunity to scarlet fever. When positive, the redness appears in about six hours, reaches its height in 18 to 24 hours and subsides promptly. The reaction is a circular area of erythema, sometimes accompanied by edema and swelling of the skin of more than 10 mm. in diameter. In quite sensitive subjects, or with very potent toxins, the erythema may be from 20 to 30 mm. or more across. Most children with scarlet fever react positively to this test until about the sixth day of the disease, when they become negative. The Dick test, therefore, also has diagnostic significance. Infants under six months of age usually give negative Dick tests irrespective of the result of the test in the mother. Thereafter, children show an increasing susceptibility until about the fourth year when it is highest. With advancing age there is a gradual decrease in the proportion of susceptibles, which varies with time, place, and circumstances, until in adult life 70 to 80 per cent may react negatively. Experience has shown that anomalies occur as with other similar tests and certain limitations to interpretation which were not at first appreciated have become apparent.

Two important sources of error have been demonstrated: (a) the confusion caused by allergic reactions to other constituents of the test material containing nucleoprotein and other substances derived from the bacterial cell and growth products, and (b) qualitative differences in the erythrogenic toxin produced by some strains of streptococci.

Although there has been some difference of opinion as to the frequency of "pseudoreaction" due to allergy, and the necessity, therefore, for a simultaneous control test, recent work has emphasized that this source of error cannot be ignored, particularly in adults.

Concerning the second source of error, although the erythrogenic toxin produced by most strains of scarlet fever streptococci is essentially similar, some degree of heterogeneity exists (Coffey, 1938). To cover the range of variation, the Dicks required that the pooled products of four selected strains be used in the manufacture of toxin and antitoxin. The scarlet fever antitoxin in routine use produced under the Dick patents neutralizes the toxins used in the Dick test, but fails to neutralize the toxins of about 10 per cent of the strains isolated from patients in the United States. When exposure to such strains occurs, one might expect even a Dick-negative person to develop scarlet fever.

With these qualifications, *the Dick test is a reliable indication of the level of scarlet fever antitoxin* in the individual's tissues. A negative Dick test does not imply an ability to resist *infection* with hemolytic streptococci of Lancefield's Group A.

**Relation of Scarlet Fever to Streptococcal Sore Throat and Other Infections.** That scarlet fever streptococci might cause infections of the throat without a rash (*sine exanthematica*) had long been suspected and was definitely established by Stevens and Dochez in 1926. They observed that such infections occurred among persons who had negative Dick reactions, implying again that immunity against erythrogenic toxin does not necessarily imply protection against sore throat and its complications. Studies of the frequency of negative Dick reactions in relation to age and a history of attack have suggested that a considerable proportion of persons, perhaps four out of every five, gain their antitoxic immunity (Dick-negative re-

action) without having had recognizable clinical attack of fever with rash. Such observations would indicate that infections with hemolytic streptococci capable of causing scarlet fever, occur far more frequently without the rash than they do with it.

Some types of Group A beta hemolytic streptococci are incapable of producing enough erythrogenic toxin to cause a rash. These types are widely distributed and at times a not inconsiderable cause of nasopharyngitis and tonsillitis, with attendant complications. Such infections are of great importance as antecedents of rheumatic fever. Despite the absence of the identifying rash, the clinical findings alone will permit an almost certain diagnosis in some cases. Characteristically, such illnesses present the sudden onset of sore throat, pain on swallowing, fever and other constitutional reactions, diffuse redness and edema of the soft palate, tonsils and oropharynx, discrete or confluent exudate, enlarged or tender cervical lymph nodes. Confirmation of the diagnosis may be obtained by laboratory procedures. Many patients will have an elevated total leukocyte count, cultures of the pharynx will almost always show a predominant growth of beta hemolytic streptococci. Depending upon the availability and use of preceding criteria, a large percentage of streptococcal respiratory infections can be readily and rapidly diagnosed, particularly during an epidemic period. The term "septic sore throat" was formerly applied to the more severe manifestations of streptococcal sore throat, particularly when it was disseminated by milk.

In this connection a study by Stebbins and others (1937) of the records of 1,529 cases of streptococcal infection occurring in seven milk-borne epidemics in New York State during the period 1934 to 1936 is most interesting. Three of these epidemics were classified as scarlet fever and four as "septic sore throat." The clinical manifestations of cases observed in the various outbreaks were strikingly similar, with the exception of the presence or absence of a characteristic scarlet fever rash and desquamation. In the three epidemics classified as scarlet fever, a typical scarlet fever rash was observed in 60 per cent of the cases; 40 per cent had no rash. The character and frequency of complications were practically the same in the "septic sore throat" cases as in the scarlet fever cases. A previous history of scarlet fever had no influence on the frequency of infection with either clinical type of infection, but was associated with a lower incidence of rash in the scarlet fever cases. Dick tests done after recovery indicated that the proportion of persons who had become negative as a result of their illness was greater among those who had had scarlet fever than among those who had septic sore throat.

The implications of this study may be extended to other human infections with hemolytic streptococci of Group A, such as otitis, mastoiditis, puerperal sepsis, wounds and burns (Longcope, 1938). Whether or not the infection is accompanied by a *scarlet rash* will depend upon the balance between two factors: (a) the ability of the invading strain to produce a sufficient quantity of erythrogenic toxin under the conditions of growth in the tissues, and (b) the ability of the host to produce sufficient quantities of the specific antitoxin to neutralize this toxin. If the rash becomes manifest or if the case is associated with others which show a rash, it is classified as "scarlet fever." If no rash becomes apparent, it is an "infection with hemolytic streptococci." Whether the rash is of importance in prognosis or only in diagnosis is not yet clear, as the ultimate outcome of the infection depends upon the



ability of the organism progressively to invade the tissues. To what extent production of erythrogenic toxin facilitates this invasion is unknown.

**Public Health Implications.** From these considerations, it appears that neither from the point of view of specificity of the etiologic organisms nor from the point of view of clinical manifestations is scarlet fever a distinct disease. Just as the hemolytic streptococci which cause it merge into the other streptococci of Lancefield Group A, so the classical disease syndrome merges into those of related infection caused by this group. Accordingly, *scarlet fever should be regarded not as a disease entity but as a clinical manifestation of infection with one of the types of the Group A hemolytic streptococci.*

It follows logically that any program of prevention should deal with this whole group of infections and not simply with those which show a rash. The group includes (1) acute primary Group A streptococcal infections involving various parts of the upper and lower respiratory tract, from a simple nasopharyngitis to pneumonia with empyema, skin and wound infections, erysipelas, puerperal fever, and their suppurative complications; (2) late nonsuppurative complications, namely, acute nephritis, and rheumatic fever. There is a latent or quiescent period of variable duration, usually two to four weeks or more between the former and the latter manifestations.

**Modes of Transmission.** The ultimate source of all Group A hemolytic streptococci is infected human beings. The individual may be suffering from any one or any combination of the clinically recognizable infectious processes mentioned above or from a subclinical or inapparent infection or carrier state. The latter are by far the more numerous. The primary site of multiplication of this microparasite in the vast majority of instances is in the upper respiratory tract, the nose, sinuses, and throat. To the extent that they are present in the secretions of the nose and throat they are projected into the environment during the acts of coughing, sneezing, talking, spitting, nose-blowing. Hamburger and others (1946, 1949) have presented evidence that nasal carriers are more important than the throat carriers in spreading streptococci. The explanation resides in the fact that the nasal carrier contaminates his environment, including the air, to a far greater extent than does the throat carrier. Carriers whose sinuses are infected, or who have rhinitis, expel larger numbers of streptococci and for a longer period of time; they are the "dangerous" carriers. To the extent that streptococci are contained in the purulent discharges from wounds and infected tissues they make their way into the environment through contaminated bandages, dressings, sheets, pillow cases, bedclothes, and other articles. In dried particles of secretions or discharges they may remain viable in dust or on blankets, or on various contaminated surfaces for weeks or months.

Transfer from one individual to another may take place by rather direct conversational contact or by various routes indirectly. It may be by contaminated articles to hand, to food, to mouth; it may be by droplet nuclei and by dust particles for short distances through the air. This is discussed in detail in Chapter 2. Contamination of foods, particularly milk and milk products, occasionally gives rise to sharp outbreaks.

The conditions required for the transmission of scarlet fever are the same as for other Group A streptococcal infections except as modified by the requirements for the production of this particular clinical syndrome. New cases of scarlet fever arise as individuals are exposed to types of hemolytic streptococci which produce erythro-

genic toxin, and as these make effective contact with the tissues of individuals who are susceptible (Dick positive). In general, hemolytic streptococci from a case of scarlet fever are more likely to be of a type which can produce scarlet fever in the new host than are organisms coming from a case of sore throat without rash.

The period of incubation is usually three to four days; extremes are 12 hours and seven days. Infections of the respiratory tract are contagious from beginning of symptoms. The danger seems to be in direct proportion to the amount of discharge from the mucous membranes of the nose, throat, and adjacent passages and the number and virulence of streptococci contained therein. Most of the uncomplicated cases, even when not treated with antibiotics or chemotherapy, are no longer infectious after one or two weeks. The desquamating flakes of skin are not infective as was formerly thought. The organism frequently persists in the throat of convalescents for months and may lose its type-specificity. This may mean a loss of virulence, loss of capacity to spread, or both. In any event, "spread" as indicated by secondary cases decreases as time elapses from the onset of initial infection regardless of whether the organism is harbored in nose or throat (Dingle and others, 1953).

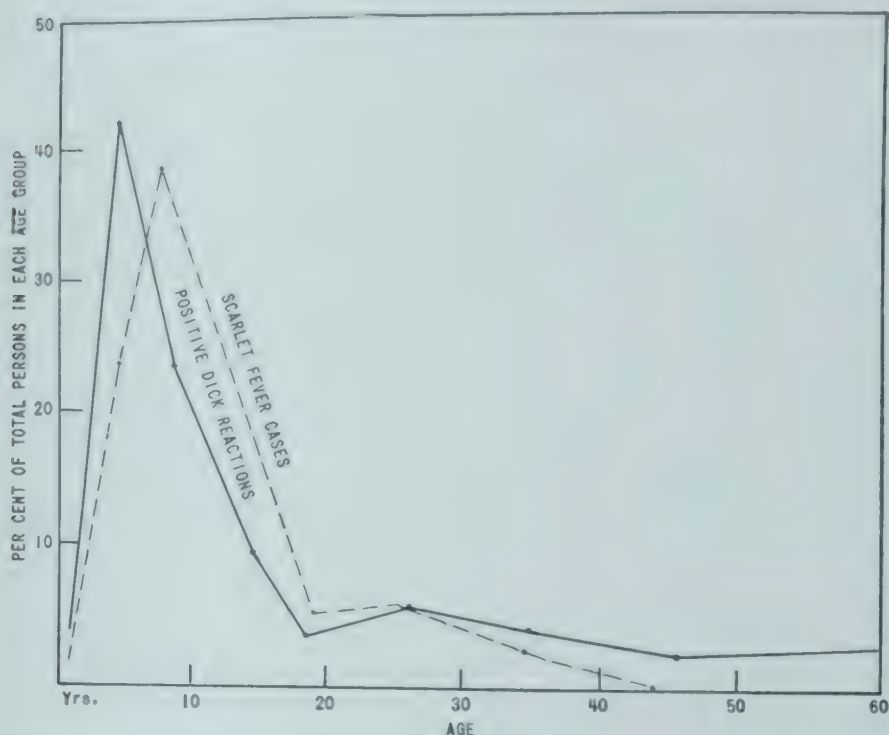
**Occurrence of Streptococcal Infections of the Respiratory Tract.** The frequency of various clinical manifestations or infections with these organisms vary within wide limits in different geographic areas and time periods. The morbidity and mortality statistics of *scarlet fever* are available from many countries and indicate the regional distribution of the types which produce this disease. The fact has long been recognized that scarlet fever is largely a disease of temperate zones and occurs but rarely in the tropics. It is interesting to note, for example, that although scarlet fever is rarely recognized in the vicinity of Rio de Janeiro, Brazil, children become Dick negative earlier in life than do children in New York City (Doull and others, 1927). Although the disease can occur in any month of the year, as the geographic location is more remote from the tropics, scarlet fever tends to show a more and more pronounced seasonal distribution. In the United States it reaches its greatest incidence from January to March; in London, over a period of 30 years, the mode of incidence fell in October and the minimum in April; in New Zealand, where the seasons are reversed, the greatest prevalence is from April to June and the lowest from November to February.

In large cities of the temperate regions scarlet fever is continuously endemic. In the smaller communities it may be absent for considerable periods of time and when introduced may prevail in an epidemic. The age distribution of scarlet fever cases closely parallels the age distribution of susceptibility as indicated by the Dick reaction (as seen in Fig. 1-8). One attack usually confers immunity for life but second attacks do occur in approximately 1 per cent of cases. Second attacks are presumably due to infection with a hemolytic streptococcus type producing an erythrogenic toxin with which the patient has had no previous experience. An individual may, however, have repeated infections with different types of Group A streptococci without rash. The "antibacterial" immunity to a particular type strain does not protect against the many other types to which the individual may be subsequently exposed.

The level of prevalence of *acute primary streptococcal infections of the respiratory tract* in any community at a given time is the result of past experience with, and the prevailing exposure to, different types of Group A hemolytic streptococci (Schwentker and others, 1943). At any given time the streptococcal flora of any



community includes a variable number of different types. The majority have practically no concurrent pathogenicity. A few are capable of causing streptococcal infections other than scarlet fever. Still fewer have the potential ability to cause scarlet fever and other streptococcal disease as well. What happens will depend in the first



From Schwentker, F. F., Janney, J. H., and Gordon, J. E., *Am. J. Hyg.*, 38:27, 1943.

Fig. 1-8. Age distribution of positive Dick reactions compared with the age distribution of cases of scarlet fever.

instance upon how favorable the conditions of living are for the rapid transmission of respiratory flora from one individual to another. This will be contingent in particular upon the degree of crowding in living, working and sleeping quarters, house-keeping cleanliness, personal hygiene, the presence of undifferentiated respiratory infections causing coughs and colds, and of predisposing infections such as measles and influenza. The second factor in the situation is the susceptibility status of the exposed population with reference to the prevailing types of Group A streptococci. This susceptibility refers primarily to what proportion of the population has acquired resistance to these particular types ("antibacterial" immunity), and secondarily to what proportion have acquired resistance to the particular erythrogenic toxins they elaborate (Dick negative). The third factor is the potential pathogenicity of the prevailing type strains. This capacity is related to those biological qualities which determine the ability of the organism to invade the tissue (virulence) and its capacity to produce erythrogenic toxin. In general, the population will be most susceptible to the types with which it has had little or no recent experience, i.e., newly introduced strains; these types then have the greatest potential ability to spread and build up a high carrier rate. As the carrier rate increases and decreases the incidence of the acute respiratory streptococcal diseases rises and falls. Thus, in any contact-trans-

mitted epidemic several types of Group A hemolytic streptococci may be found, but one type usually predominates both among carriers and among patients. The prevalent clinical pattern, that is, whether cases are largely scarlet fever, or are streptococcal nasopharyngitis, tonsillitis or septic sore throat, will be determined by the pathogenic potentiality of this type.

The manner in which streptococcal infections spread through different organizations and from one organization to another in the U. S. Navy during World War II, the importance of this cause of man-days lost, the factors determining distribution and frequency, and the measures taken to decrease incidence have been described in interesting detail by Coburn and Young (1949).

**Food-Borne Outbreaks.** Contaminated milk may occasionally give rise to widespread and spectacular outbreaks of scarlet fever and streptococcal sore throat. A classic example is an outbreak of septic sore throat in Baltimore, Maryland, investigated by Frost (1912). It was estimated that not less than 1,000, and perhaps as many as 3,000 cases, occurred in this outbreak, causing 30 or more deaths. Apparently the milk supply in question became infected prior to its receipt at the distributing plant and the infective agent survived the inadequate "flash" process of pasteurization employed at that time. In the 25-year period from 1917 to 1941 a total of 160 outbreaks of milk-borne disease were investigated by the New York State Department of Health (Dublin and others, 1943). Septic sore throat and scarlet fever outbreaks comprised 34 per cent of those studied and contributed 68.2 per cent of all the cases. They were exceeded in importance only by outbreaks of typhoid and paratyphoid fever. Between 1935 and 1942 nine outbreaks were investigated in which serologically typed streptococci were incriminated. In eight out of the nine outbreaks the mode of contamination of the milk was through infection of the cow's udder. The usual history is that the cow has suffered a teat injury followed by development of acute mastitis due to manipulation of the injured part by a person with a sore throat.

Ice cream is seldom mentioned in the literature as a vehicle for the transmission of scarlet fever, but Ramsey (1925) reports one such outbreak occurring in Flint, Michigan. One hundred and sixteen cases of scarlet fever were traced to consumption of a particular ice cream. The evidence indicated that the ice cream mix before freezing had been contaminated by the ice cream maker who had scarlet fever.

During World War II, a food-borne outbreak of tonsillitis and pharyngitis due to beta hemolytic streptococcus Type 5 was carefully investigated by the Commission on Acute Respiratory Diseases (1945) at Fort Bragg, North Carolina. The infection was probably acquired from contaminated creamed eggs served at breakfast. The median incubation period for primary cases was 38 hours. Among 228 exposed to risk, there were 86 cases and 9 carriers. The secondary attack rate among their contacts was 30.1 per cent, of whom approximately one-half were cases and one-half carriers.

**Artificial Immunization Against Scarlet Fever.** Following discovery of the role of erythrogenic toxin in the etiology of scarlet fever, the possibilities of conferring artificial immunity, both actively and passively, were explored. Treatment of patients by whole blood transfusion from immune donors was found to be a valuable therapeutic procedure in the more severe cases. Antitoxic horse serum was produced and used in treatment and for conferring temporary passive protection against scarlet



fever upon exposed susceptible contacts. The latter procedure is of questionable effectiveness and incurs the risk of serum sickness.

A method of active immunization was also developed and advocated. It required the repeated subcutaneous injection of erythrogenic toxin in graduated doses. Five subcutaneous injections of 500, 2,000, 8,000, 25,000 and 80,000 skin test doses of erythrogenic toxin, spaced at intervals of one week were recommended. Two weeks after the last immunizing dose the Dick test was performed and in 85 or more per cent of individuals reaction was changed from positive to negative. In practice, this method of active immunization was restricted almost entirely to nurses and internes and persons confined to institutions. There were practical objections to its use because of the large number of injections required and the frequency and relative severity of the reaction which followed one or more of these injections. Modifications have been proposed. There is evidence that active immunity thus produced protects the individual against the clinical syndrome of scarlet fever for some time. Evidence is less convincing that it protects against infections with Group A hemolytic streptococci without rash, and the attendant complications. Today in the United States there is little demand for active immunization against scarlet fever because of the current mildness of this disease and because it has been largely stripped of its terror by modern therapy.

**Control.** For similar reasons, and with better understanding of the epidemiology of streptococcal infections in general, our ideas of administrative measures instituted for the control of scarlet fever have been modified.

In English cities some half century ago, contagious disease hospitals were built on an extensive scale with the idea that hospitalization would control acute infectious disease. A number of cities hospitalized 95 per cent of the scarlet fever cases. Careful studies were made of the number of return cases coming to the hospital from families to which a scarlet fever patient had been discharged after varying periods of detention. For example, Leech in a study of 15,000 cases found that the percentage of return cases was 1.86 after an average period of 49 days or under; 1.12 per cent after an average period of 50 to 56 days; and 1 per cent when the isolation was extended 57 to 65 days. Despite these heroic and expensive measures of isolation, returned cases continued to occur. It is now accepted that this is inevitable. An occasional patient will continue to discharge hemolytic streptococci for weeks or months after recovery from acute illness. There is no convincing evidence that even in cities where hospitalization of scarlet fever patients was practically complete that this was a factor in decreasing the morbidity rate from this disease.

Up to a decade or two ago most large American cities required that cases of scarlet fever be isolated for a period of 28 to 30 days. Gradually, the futility of this procedure has been realized and more rational regulations adopted. It has been realized for some time that the isolation of frank clinical cases was relatively ineffective in preventing spread. This has become more evident as the disease has become milder in character and an increasing proportion of infections were missed and unreported or were not clinically identifiable. Moreover, there has been a growing realization that it is unreasonable to impose isolation measures on patients suffering from infection with Group A beta hemolytic streptococci simply because they had a scarlatina form rash and not to impose the same measures on patients suffering from infections with the same micro-organisms but without rash, whether the localization

of the respiratory tract or wounded tissues elsewhere in the body, whether the case required medical or surgical treatment, or both. Current practice emphasizes the desirability of the identification not only of cases of scarlet fever but of all infections with Group A beta hemolytic streptococci by adequate provision for clinical observation and bacteriological culture. Patients suspected of infection with Group A beta hemolytic streptococci should be isolated pending bacteriological diagnosis if laboratory facilities be available. They should be placed upon infectious precautions in a single room, a cubicle or a small ward, depending upon circumstances. The isolation period, whether in home or hospital, should be determined on the basis of clinical recovery but should not be less than seven days from onset. If the patient has received appropriate treatment with a chemotherapeutic or antibiotic agent, the period of communicability will have been shortened. In complicated cases isolation should be continued until discharges from suppurative lesions cease. Particular attention should be given to the so-called dangerous carrier—that is, the individual with a nasopharyngitis and sinusitis who is eliminating large numbers of streptococci in his secretions. To require that cultures of the nose and throat be negative for hemolytic streptococci before discharge is not practical. The organisms may be too few to be of significance or they may be nonpathogenic strains. At the termination of the isolation period, the room which the patient occupied should be thoroughly cleaned. Contaminated objects, floors and other horizontal surfaces, such as table tops and window sills, should be washed with soap and water. Blankets should be washed. Particular care should be taken that all dust and lint particles are removed from the room.

Restrictions upon familial contacts of a case should be imposed at the discretion of the attending physician in collaboration with local health authorities. Persons with symptoms of infection should be excluded from handling milk or other food subject to contamination. Under some circumstances it may be advisable to exclude all children in the household who have not previously had the disease from school for one week after the last possible exposure.

The prevention of excessive prevalence of scarlet fever and streptococcal diseases in schools, institutions, barracks, and similar groups is very largely a matter of avoiding overcrowding and of maintaining good housekeeping and personal cleanliness. Particular attention should be given to dust suppression (Coburn and Young, 1949). Repeated attempts to control the environment with ultraviolet light, germicidal mists and the oiling of floors and blankets have had little effect on the spread of hemolytic streptococci (Loosli and others, 1952).

Any group of cases of scarlet fever or streptococcal sore throat occurring in a short period of time should be investigated to ascertain whether or not there has been a common medium of dissemination through milk or other food. Whether schools should be closed during an outbreak varies with circumstances. In remote rural districts, where the children can be kept apart, this may be advisable, but in cities little can be gained. Better results can be obtained by daily inspection, by physician or nurse, of children for one week after exposure.

**Mass Chemoprophylaxis.** With the discovery of the effectiveness of the sulfonamides in the treatment of streptococcal infections, came the concept that the same drugs could be used to shorten and suppress the carrier state. During World War II



this was extended to the idea that the spread of hemolytic streptococci throughout a command of troops could be checked and reduced by the administration of adequate doses of the sulfonamide drugs to the entire personnel. This was tried by the U. S. Navy on an extensive scale. The experiment has been described in detail by Coburn and Young (1949). While drug prophylaxis was quite effective in temporary suppression of the carrier state and reduction in the carrier rate, certain distinct disadvantages became evident. The first was the risk of toxic effects of the drug itself to the occasional individual who was sensitive. The second objection was that mass prophylaxis led to the development of sulfonamide-resistant strains of hemolytic streptococci. These resistant strains could no longer be controlled either prophylactically or therapeutically by the drugs. In spite of these disadvantages there may be situations in smaller population units, such as schools and institutions, where it is possible under careful medical supervision to use chemoprophylaxis temporarily and briefly to reduce the carrier rate.

### ERYSIPELAS

References to a clinical syndrome designated as erysipelas appear in the earliest medical writings of antiquity. At one time it was known as St. Anthony's fire.

Hirsch defined it as "an infective inflammation-disease of the skin or one of the mucous membranes near to the external surface of the body (mouth, throat, vagina, etc.), which in all probability proceeds invariably from a solution of continuity or wound, and is characterized by its rapid extension over the surface, and by the infective fever that accompanies the local process; the latter in many cases is confined to the skin and in such cases mostly heals rapidly, leaving no permanent effects; but in other cases it extends to the subcutaneous tissue sometimes to even still more deeply situated parts, and leads to more or less considerable suppurations spreading along the surface." With the development of an effective general resistance, fever and toxic symptoms subside, local extension stops and recovery begins.

Although it still occurs sporadically, a century ago it was one of the most serious complications of wounds, whether inflicted traumatically or surgically. At times it prevailed in epidemics in lying-in and foundling hospitals, lunatic asylums, educational institutions, ships, and the like. Hirsch gives a chronological table of some 68 epidemics of malignant erysipelas which occurred in America from 1822 to 1881. He states that from 1841 onward the disease grew into a pandemic which did not cease until the beginning of the sixties. It is notable that only occasional, more isolated outbreaks were reported in the latter part of the nineteenth century. The decrease began before conscious precautions were instituted and before the disease was well understood.

In 1883 Fehleisen grew streptococci in pure culture from excised erysipelas lesions and produced the disease experimentally in human beings. Histological studies revealed that the inflammation involved mainly the superficial lymphatic vessels which were crammed with fibrin, leukocytes and chains of streptococci. There was also edema of the perilymphatic tissues. The peculiar evolution is due to the progressively diffuse lymphatic involvement. It seems probable that streptococci always gain entrance into the skin through some abrasion, although this initial site is not always demonstrable. It is now known that in nearly all instances some type

of Group A hemolytic streptococci is the cause of this clinical syndrome; rarely is it due to Group C streptococci.

With the introduction of surgical asepsis, erysipelas became more and more infrequent in occurrence until it was largely limited to debilitated infants and old people. The complete clinical picture is rarely seen today since adequate antibiotic therapy quickly arrests its progress.

#### PUERPERAL SEPSIS

(*Childbed Fever*)

It was long ago noticed that childbed fever was somehow associated with erysipelas, scarlet fever and with other infections. Notes regarding its contagious and epidemic character are found in the literature. Among these are the observations of Malouin at the Hôtel Dieu in 1746 and of Gordon at Aberdeen in 1795. Charles White of Manchester, England, in 1773 was a pioneer in antiseptic midwifery. On February 13, 1843, Oliver Wendell Holmes read his paper "On the Contagiousness of Puerperal Fever." He said: "The disease known as puerperal fever is so far contagious as to be frequently carried from patient to patient by physicians and nurses." He presented evidence that the doctor who went from the autopsy table or from cases of erysipelas or sepsis carried the infection to women in childbirth. Semmelweis, in the Allgemeines Krankenhaus in Vienna, noticed a greater incidence of puerperal sepsis in the wards served by students, who often came from the autopsy room to attend deliveries, than in the ward used for instruction of midwives. Next, he noted at the autopsy of a friend dead of a dissecting wound the same pathology as that found in childbed fever. He immediately (1847) instituted disinfection of the hands with chlorinated lime and the mortality fell from 9.9 to 3.8 per cent, and to 1.3 per cent the following year. Both Holmes and Semmelweis met determined opposition. It was difficult for the physician to admit that he was the cause and carrier of fatal infection to his patients. Semmelweis was a martyr to his faith. He had a tragic end.

It was almost a half century later before laboratory evidence was produced which supported the concepts of these pioneer investigators. Bacteriological research led to improvement in obstetrical care which resulted in reduction of the death rate from puerperal fever from approximately 7 or 8 per 1,000 deliveries to less than a fraction of 1 per cent.

Following childbirth, the female genital tract inevitably presents wounded surfaces—endometrial areas from which the placenta has been stripped, cervical lacerations, and perineal tears. These wounded tissues become a *locus minoris resistentiæ* in which bacteria, particularly streptococci, easily proliferate. The source of the invading micro-organisms may be endogenous, since the normal vagina is often inhabited by many varieties of streptococci. However, they are usually introduced from exogenous sources. They may come from (1) the secretions of the patient's own nasopharynx; (2) from other patients having streptococcal diseases or wound infections; (3) from the nasopharynges of the attending physician or nurses; (4) from contaminated articles, instruments or clothing, or from the contaminated dust and lint in wards and operating rooms. If the puerperal fever is due to infection with Group A streptococci, serious and often fatal complications may



quickly ensues unless appropriate chemotherapy or antibiotic treatment is promptly instituted.

### EPIDEMIC NEPHRITIS

It has long been known that acute glomerulonephritis occurred as a late non-suppurative complication of scarlet fever. The incidence of this complication has decreased in the past several decades as the disease has become milder. More impressive is the fact that its frequency is extremely variable from year to year and in different epidemics. Occasionally, an unusually high incidence of acute nephritis has been recorded both in widespread epidemics and in focal outbreaks in small population units, associated with sore throat, with or without rash, and due to Group A hemolytic streptococci. A recent review of the literature (Rammelkamp and Weaver, 1953) suggests very strongly that the variations in the attack rate are determined by varying nephritogenic capacities of the infecting type and strain of microparasite. They have been associated particularly with type 4 or 12. Nephritic complications due to these types usually follow the acute streptococcal illness after a latent period of one to two weeks.

### RHEUMATIC FEVER

During the past century the concept of rheumatic fever as an entity slowly emerged from the joint diseases included under the vague term "rheumatism." Haygarth, in 1805, was the first to write a clinical monograph associating rheumatic fever with heart disease. Its infectious nature was suspected toward the end of the century. In 1904, Aschoff described what he believed to be specific histological lesions in the myocardium of individuals dying during the active stage of the disease. The Aschoff body came to be regarded by some as a specific reaction to an unknown specific etiological agent. Gradually the milder forms of this disease process were recognized.

It is now accepted that the most important manifestations are migratory polyarthritides, carditis, chorea, subcutaneous nodules, erythema marginatum. Of less diagnostic importance are fever, rapid pulse rate, nontraumatic epistaxis, abdominal and precordial pain, pallor, anorexia, weight loss, elevation of the erythrocyte sedimentation rate, leukocytosis, and electrocardiographic changes, chiefly the prolongation of the P-R interval. Any combination of these symptoms may occur. In its milder manifestations onset may be insidious and diagnosis difficult (Jones, 1944). Definite and even severe heart disease may develop in the absence of other clinical evidence. On the other hand, acute rheumatic attacks may develop quickly into a fulminating form and death may occur within a few days or weeks, or the course may be prolonged lasting months or even years with periods of activity interspersed with periods of quiescence. Characteristically the disease is very prone to recur, particularly during the first five or six years following the initial attack. Rheumatic fever is by all odds the commonest cause of heart disease in children and young adults.

**Occurrence.** For concepts of the frequency and distribution of rheumatic fever in various population groups recourse must be had to indirect sources of information and special studies. The use of mortality statistics is limited, because all too

often when patients with rheumatic heart disease die, they are labelled merely as having had heart disease without further qualifications as to etiology. The criteria employed in attributing a death from heart disease to the rheumatic fever process has varied with time and still has a wide variability in different areas of medical practice. Nevertheless, mortality from heart disease may be utilized as an index of the importance of rheumatic fever. Hedley (1937) found that for the city of Philadelphia, in 1936, the total mortality from rheumatic heart disease was about 25 to 30 per 100,000. Among infectious diseases this rate was exceeded as a cause of death only by tuberculosis, lobar pneumonia, and syphilis.

There are relatively few countries where compulsory reporting of rheumatic fever has been tried and where good results have been obtained; Norway, Denmark and Iceland were among the first. In these countries, estimates of the annual incidence of rheumatic fever fall in the range of about 1 to 2 per 1,000 population at all ages.

Most of the information regarding the distribution of rheumatic fever in different population groups has been obtained from special studies. These have been of several sorts: analyses of the experience of special rheumatic clinics and of hospital admissions, surveys to determine rheumatic fever prevalence among special groups such as school children, college students, recruits for the Army and Navy, industrial workers, or even of whole communities. Information from these various sources has been assembled and reviewed by Paul (1943) and by Wilson (1940). A few of the salient features may be mentioned.

Available evidence indicates that rheumatic carditis is prevalent and severe between the latitudes of  $50^{\circ}$  and  $40^{\circ}$  north, it diminishes in warmer climates, is almost unknown between the Tropics of Cancer and Capricorn, increases again as cooler climates are reached and is common between  $30^{\circ}$  and  $40^{\circ}$  south. There is also evidence that population groups living in certain limited geographic areas have a much higher mortality rate from this cause than others, as, for example, appears to be the case in a group of northwestern states, Montana, Wyoming, Colorado, Utah. There is a distinct seasonal variation in the incidence of rheumatic attacks. It is well established that in temperate climates both primary and recurrent attacks occur more frequently during the colder months of the year.

Rheumatic fever is rare in infants, but begins to occur in children about three years of age. Thereafter, its relative incidence steadily increases for seven or eight years, then drops during school age. But, although susceptibility to first and recurrent attacks declines rapidly in the years after puberty, rheumatic fever cannot be regarded clinically as a disease of childhood, for active rheumatic carditis and polyarthritis are common enough during adolescence and young adult life. First attacks may even be encountered in the fifth or sixth decades.

In a large number of studies the relationship between rheumatic fever and living conditions has been evident. The disease is acquired at a higher rate in cities than in rural areas and is more prevalent among people who are subjected to crowding within their homes. The urban prevalence of rheumatic fever is higher in the areas of lower economic status. There is general agreement that rheumatic fever tends to show familial aggregation. Wilson and Schweitzer have assembled evidence which



suggests that an underlying hereditary predisposition to rheumatic fever exists. It is difficult or impossible, however, to be sure that this apparent hereditary influence cannot be explained by common living conditions, environmental factors, and exposure.

**Relation with Beta Hemolytic Streptococcal Infections.** Association of rheumatic fever with sore throat was noted a great many years ago. As early as 1886 there were records of epidemics of rheumatic fever preceded by epidemics of tonsillitis. In more recent years it has become evident that the association was limited to tonsillitis caused by Group A beta hemolytic streptococcal infections. It is apparent not only in relation to initial attacks but holds as well for recurrences. Although not invariably demonstrable clinically and bacteriologically, failures may reasonably be attributed to brief mild, missed, or inapparent infections. Studies of the antibody content (antistreptolysin O) of patients' sera support this concept. Many of the epidemiological features of the two diseases are roughly parallel, particularly the geographic, seasonal, age, and socio-economic distributions. Atwater (1927) and Rosenau (1928) pointed out on the basis of mortality statistics that a "high year" for rheumatic fever was also a "high year" for streptococcal infections. The same opinion was reached on the basis of urban morbidity statistics on the two diseases; a ten-year study of annual fluctuations in prevalence within the city of New Haven, Connecticut, 1929-1938 (Farquhar and Paul, 1940) indicated that a "high year" for tonsillitis and erysipelas was likely to be also a "high year" for rheumatic fever.

Observations on smaller population units in schools, institutions, military and naval installations, made during the past 10 or 15 years, have uniformly come to the conclusion that epidemics of rheumatic fever in which the antecedents have been observed both clinically and bacteriologically, have been found either to follow or to have been associated in some way with the prevalence of hemolytic streptococcal infections. Madsen and Kalbak (1940) described a number of explosive epidemics of rheumatic fever which followed milk-borne epidemics of streptococcal sore throat.

During the past few years, post-tonsillitis barrack epidemics of rheumatic fever have been repeatedly observed. There is no doubt but what they may assume serious enough proportions in both the Army and Navy to represent a major problem in preventive military medicine (Coburn and Young, 1949). In the experience of the Armed Forces in the United States there was an average of 7,300 cases annually for the seven-year period 1942 through 1948. A conservative estimate of the cost of each case that occurs in the Armed Forces is \$16,000.

**Prevention by Therapy.** Attempts to prevent the occurrence or the recurrence of rheumatic fever during the past decade have centered around treatment of the streptococcal disease which precedes most cases of rheumatic fever. Coburn (1944), Kuttner and Reyersbach (1943) and Hodges (1944) showed that sulfonamide drugs given prophylactically not only reduced the incidence of streptococcal disease but also reduced the recurrence of rheumatic fever. This would seem to be a practical means of prevention in two situations: (a) closed groups in which the incidence of streptococcal disease is extremely high, and (b) in selected groups such as patients with inactive rheumatic fever or rheumatic heart disease where the danger of recurrence is great. This method of prevention has not proven to be practical for the general population, however, because of the toxicity of the sulfonamide drugs

and the high percentage of sulfonamide-resistant strains of streptococci that develop and the difficulty that is entailed in mass prophylaxis (Coburn and Young, 1949). Treatment after the development of the streptococcal infection with sulfonamide drugs has proved to be ineffective. The oral administration of penicillin also appears to be valuable in prophylaxis or recurrences (Kohn and others, 1950). Although penicillin, chlortetracycline, oxytetracycline and erythromycin are effective in alleviating the symptoms of acute streptococcal diseases, only penicillin and chlortetracycline therapy have been shown to reduce the incidence of rheumatic fever following such infections. Chamovitz and others (1954) recommended that penicillin be administered so that effective concentrations are maintained for at least ten days. This may be accomplished by a single intramuscular injection of 600,000 to 900,000 units of benzathine penicillin G or by the oral administration of 250,000 to 500,000 units of penicillin twice daily for ten days.

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#### DIPHTHERIA

The occurrence of diphtheria can be traced back into the medical writings of antiquity. Most medical historians are agreed that the description given by Aretaeus the Cappadocian, in the second century, of the Egyptian or Syriac ulcer can be identified with some degree of certainty as diphtheria. He gave a clear account of a severe inflammatory disease of the throat, particularly in children, associated with the production of a whitish or discolored concretion which might extend into the mouth or descend into the windpipe causing dyspnoea or suffocation. Throughout the middle ages there are many references to a clinical syndrome of this kind and to epidemics of what was commonly called malignant angina. The first recognizable account of what was subsequently called "croup" was in the writings of Baillou (Ballonius) in 1576. In 1765, Francis Home of Edinburgh published his classical monograph entitled "An Enquiry into the nature, cause and cure of croup." He distinguished an inflammatory or catarrhal form less dangerous, and a purulent or membranous form very dangerous, which he regarded as different stages of the disease. The classical monograph of Pierre Bretonneau, the French clinician, often referred to as "Traité de la diphthérie," was published in 1826. By unsurpassed powers of clinical observation and generalizations based on accurate records and postmortem studies of a large number of cases, he formulated his doctrine of diphtherite (anglicized to diphtheritis) as a specific disease. The concept of croup was swept away or merged in that of diphtherite. Bretonneau argued for the specificity

of the peculiar exudate or membrane. The affected part is usually the throat, larynx, or trachea, but the disease may be on some other part such as a blistered surface of the skin, a cutaneous diphthérite.\* His differential diagnosis was based upon the pathological-anatomical characteristics of the disease process.

Although Bretonneau warned against confusing diphtheria with other diseases of the throat like it, those who came after him were inclined to diagnose everything as diphtheria which looked like diphtheria. There was some question as to whether scarlet fever and diphtheria were not identical, and difference of opinion as to the relation of croup to diphtheria. This confusion could not be resolved until the etiology was established and a bacteriological diagnosis and confirmation was possible. It was, therefore, well on to the end of the nineteenth century before diphtheria came to be distinctly differentiated from other infections of the nose and throat.

The knowledge of the etiological agent begins with the publication of Loeffler's report in 1884. Klebs had described the bacillus in the diphtheritic membrane in the previous year but had brought forth no convincing evidence of its causal relationship. In 1888, Roux and Yersin demonstrated the exotoxin and in 1890 Von Behring and Kitasato developed the antitoxin. Subsequent investigations have confirmed and extended the observations of these pioneers and today there is available a fairly detailed knowledge of the etiology, pathogenesis and epidemiology of diphtheria.

**The Disease.** Diphtheria is a specific infection due to the Klebs-Loeffler bacillus (*Corynebacterium diphtheriae*). It often begins insidiously without pain or local indications and with little or no fever. The disease may exist several days before it is noticed. Both from the standpoint of prevention and cure, early recognition is of prime importance. The period of incubation is from two to seven days, usually two.

The disease is characterized by a local fibrinous exudate, usually upon the mucous membrane of the throat, but it may affect other mucous membranes, the conjunctivae or wounds in any part of the body. The bacilli remain in the local lesion where they grow and multiply. There they produce a soluble poison, the diphtheria toxin, which is absorbed and causes the toxic symptoms. The serious nature of diphtheria may be due to the intense local inflammation, to the toxemia, or to complicating septic micro-organisms. The local inflammation is characterized by coagulation necrosis, fibrinous exudate and the formation of a grayish membrane. The process is due to the local irritating effect of the diphtheria bacillus and certain of its products, and is attended with congestion and edema. When in the larynx or trachea, death may result mechanically from suffocation. The local process is self-limited as a result of tissue reaction against the bacillus and its bacillary products, whereas the toxemia is neutralized with antitoxin.

The toxemia produces acute degenerative changes in the cells of various organs of the body. According to their extent and intensity these give rise to serious and sometimes fatal complications. The degenerative changes in the myocardium and the central nervous system are of particular importance. The former give rise to

\* In England, the word "diphtheria" was introduced by Farr in the Registrar General's report for 1858 on the ground that "the termination *itis* as in gastritis is used in medical language to designate pure inflammation of an organ which the root of the word expresses, hence *ia* has been substituted for *ite*, the French form of *itis*, as this cannot with any propriety be placed after *diphthera* designating a product of disease and not an organ of the body."



myocarditis. This occurs most frequently in the severe forms of the disease but may be found in cases which seem to be only mildly ill. In some instances, the presence of myocarditis can be determined only by careful examination. It may remain unsuspected until the sudden development of myocardial failure makes it evident. The signs of myocardial failure may first appear during convalescence and sudden death may occur several weeks after recovery. As a result of the degenerative changes in the central nervous system some form of paralysis occurs in from 10 to 20 per cent of cases of clinical diphtheria. Although the probability of its occurrence and its extent are usually related to the severity of the attack, it may occur after a mild attack, especially one that was unrecognized and therefore not treated with antitoxin. The muscles of the soft palate are usually the first and may be the only ones involved. Generally, however, other muscles are affected, especially those of accommodation, less frequently the extra-ocular muscles, the pharynx, diaphragm, and the muscles of the upper and lower extremities. In severe cases, on the fifth or sixth day there may be present signs of paralysis consisting of nasal voice and regurgitation of fluids through the nose. This, however, does not usually occur until the second week. The later it occurs the less likely the paralysis will be widespread. Knee jerks are frequently absent even when the process is very limited in extent.

Every gradation in severity and extent of complications is encountered. At one extreme there is a form which goes under the name of malignant diphtheria which is fatal early and is frequently associated with the presence of Group A beta hemolytic streptococci. In this form there is a marked swelling of the cervical glands and frequently extensive infiltration of the cellular tissue of the neck so that the head is thrown back to relieve pressure upon the larynx and trachea. The swelling sometimes forms a distinct collar, reaching from ear to ear, filling the whole space beneath the jaw ("bull neck"). By contrast, in some patients, the symptoms are no more severe than those of a simple sore throat.

Death in diphtheria may result from the toxemia, laryngeal stenosis, bronchopneumonia, late myocardial failure or respiratory paralysis. The case fatality rate varies with the virulence of the prevailing strains of *C. diphtheriae* in different outbreaks and in the same outbreak, with age and medical care. It is highest in the first two years of life. In diphtheria hospitals the mortality in children under two formerly varied from 60 to 80 per cent. The risk has been greatly reduced by modern methods of treatment.

**Diagnosis.** The diagnosis of diphtheria often rests upon a combination of clinical symptoms and laboratory findings. Positive cultures alone do not necessarily mean clinical diphtheria, even though sore throat and fever may be present. Cases of streptococcal tonsillitis, with follicular patches resembling false membrane, occur in diphtheria bacillus carriers. On the other hand, repeated negative cultures are significant in excluding diphtheria, provided the material is taken from the proper places and good technic is used. Diphtheria bacilli do not always lie on the surface and it is advisable to rub the membrane a bit roughly in taking specimens for cultures.

A presumptive diagnosis of a case suspected on clinical grounds can be made if typical *C. diphtheriae* are found in a stained film spread directly from a swab taken from the suspected lesion. However, the swab is rubbed customarily on a slant

of Loeffler's medium and the culture examined within 18 to 24 hours. The latter procedure is generally accepted as the standard technic, although the pleomorphism of the *C. diphtheriae* and the existence of the diphtheroids again interfere with the certainty of the findings. Isolation of the organism in pure culture employing a selective medium containing a bacteriostatic agent such as tellurite is the only certain method. With this technic the organism may, in addition, be tested for virulence. Many laboratories are employing a combination of the technics, inoculating a Loeffler's slant and later a tellurite plate. This provides for a rapid tentative diagnosis and permits further work with the organism in pure culture to determine whether it is a virulent or avirulent strain of *C. diphtheriae* (Am. Pub. Health Ass'n, 1950).

**Treatment.** Early recognition is extremely important, both for successful treatment of the clinical attack and for control of the spread of the infection. Always give antitoxin at once in a clinical case of diphtheria without waiting for bacteriological confirmation of the diagnosis. Time is the important element in the life-saving properties of antitoxin. The patient should be first tested for sensitivity to horse serum by intradermal injection. If there is no immediate reaction, 20,000 to 80,000 units of antitoxin should be given in a single dose, depending upon duration of symptoms and severity. Ordinarily the antitoxin is injected intramuscularly, but in severe cases part of the dose should be given intravenously. In addition penicillin may be administered, but it is not a substitute for antitoxin. Neither antitoxin nor penicillin can be relied upon to shorten the convalescent-stage carrier.

**Etiology.** The Klebs-Loeffler bacillus, *Corynebacterium diphtheriae*, is Gram positive, nonmotile, nonsporeforming, nonencapsulated and nonfilamentous. Occasionally slight branching forms and club-shaped cells are found. A feature which characterizes this organism, serving to differentiate it from some, but not all, of the related "diphtheroids," is the presence of the metachromatic granules which are demonstrated when the bacilli are stained with a suitable preparation of methylene blue.

The discovery of natural antitoxin in the circulating blood of horses employed for biological purposes prompted a fruitless search for an extrahuman host for *C. diphtheriae*. Other domestic animals, especially cats, dogs and fowl, have been suspected as sources of human infections, but evidence that there is any natural host species other than man is lacking. The cow was also considered, but it is reasonably certain now that this animal is not naturally infected, although pre-existing superficial lesions on the teats may be infected via the hands of milkers.

The diphtheria bacillus is, therefore, an obligate parasite of man. It has less resistance to adverse environmental conditions than do the majority of the spore-free bacteria. It is more readily destroyed by light, heat and disinfectants than is the typhoid bacillus, corresponding in this regard more to the frailer streptococci. The organism can resist drying for a long time when enclosed in the flakes of false membrane or protected in albuminous matter, and they may remain viable and virulent for some months under these circumstances. It is not killed by freezing but it is destroyed if held at 60° C for 20 minutes.

**Virulent and Avirulent Strains.** There exist nontoxigenic or avirulent strains of this organism that, while conforming to morphological and cultural attributes,



fail to form toxin in demonstrable quantities. The avirulent diphtheria bacilli do not produce toxin in demonstrable amounts, do not kill guinea pigs, and do not produce antitoxins. Toxigenicity, or virulence, is a stable strain characteristic; rarely is it lost. Freeman (1951) described the development of toxigenic strains of *C. diphtheriae* from cultures of avirulent *C. diphtheriae* as the result of the action of a specific bacteriophage. The occurrence of this phenomenon has been confirmed and defined more precisely by further studies (Frobisher and Parsons, 1953). Presumably, this change occasionally takes place in nature.

The most reliable test for toxin production or virulence is the classical method, consisting of the subcutaneous injection of 0.5 to 1.0 ml. of heavy saline suspension of a pure culture into a normal 250- to 300-gram guinea pig and into an antitoxin-protected control. Death of the unprotected animal or the appearance of a definite local lesion, and absence of any change in the control is accepted as evidence of virulence. The intracutaneous injection of pure cultures was introduced to conserve animals and has supplanted the original technic in most laboratories. Several suspensions may be injected in 0.1 ml. amounts into the shaved skin of the back of a rabbit or guinea pig. After four to seven hours, about 500 units of antitoxin are injected intravenously or intracardially and equal doses of the same suspensions are injected immediately afterwards at sites near the original ones. The toxin, if present, will cause a specific local inflammatory reaction with a superficial necrosis of the skin at the original sites of injection. The antitoxin prevents a lesion in the skin at the site of the control injections (Am. Pub. Health Ass'n, 1950).

An in vitro method of testing *C. diphtheriae* for virulence has been worked out by Elek (1948). With certain modifications it has been found by King and others (1950) to be a simpler, less expensive and more rapid method for determining virulence than any of the animal tests formerly used. This test is based upon the principle of toxin-antitoxin flocculation visible in an inoculated agar plate.

**Cultural Types of Diphtheria Bacilli.** Anderson and others (1931) proposed a classification of types of diphtheria bacilli on the basis of certain cultural characteristics. The differentiation was made (Am. Pub. Health Ass'n, 1950) on the basis of the appearance of colonies upon tellurite media, fermentation of glycogen, fermentation of starch, hemolysis from blood agar, growth in broth and morphology. Correlation appeared to exist between the severity of the course of the disease and the types of organisms recovered, which were consequently given the name of *gravis*, *mitis*, and *intermedius*. From further work it appeared that there are additional types not readily differentiated by the same criteria or occasional atypical and transitional forms. Frobisher and others (1945) described an additional type which was called *C. diphtheriae minimus* on account of the small size of the colonies on tellurite medium. Virulent and avirulent strains of all cultural types have been found to exist. Diphtheria toxin produced by all types is neutralized by the same antitoxin. Whether the terms "*gravis*" and "*mitis*" are wisely chosen or not is debatable. McLeod (1943) reviewed the evidence supporting the concept that *gravis* was associated with the more severe types of the disease. This has been questioned by other observers. The correlation between the type differentiation based upon these selected cultural characteristics and potential pathogenicity is not yet clearly established. Attempts to differentiate types immunologically on the basis of the antigenic composition of the

somatic substances of diphtheria bacilli, while showing differences, have not contributed a useful classification.

**Schick Test.** Early studies indicated that recovery from diphtheria depended upon the mobilization in the blood stream of sufficient amounts of antitoxin to neutralize the maximum quantities of the toxin liberated from the local area of infection with *C. diphtheriae*. In 1909, Römer, using a technic of titration on the skin of a guinea pig, fixed the level required for the protection of human beings against clinical attack at approximately 1/30 of a unit of antitoxin per milliliter of blood serum. Schick (1913) utilized this principle to develop a method by which a cutaneous test could be directly observed to determine whether or not an individual had circulating antitoxin in sufficient quantities for protection. The test depends upon the fact that diphtheria toxin exerts a local destructive or irritating action upon tissue. If at the point of injection there is a sufficient amount of antitoxin in the tissue fluids to neutralize the toxin, no injury occurs.

In practice, the test is made by the intracutaneous injection of diphtheria toxin so diluted that 1/50 mld. is contained in 0.1 ml. of a properly buffered diluent. Customarily the injection of this amount of toxic filtrate is made into the skin of the flexor surface of the forearm. As a control, a similar injection is made into the skin of the opposite forearm of the same material which has been heated to 60° for 15 minutes to inactivate the toxin. The control material, therefore, contains the broth elements in which the diphtheria bacillus was grown and the heat stable growth products of the organisms. Occasionally, a slight degree of edema appears around both injection sites within a few minutes but disappears very shortly. The injection areas should be examined at 48 hours and again at the end of from four to seven days. The following types of reaction can be distinguished.

The *positive* reaction consists of a circumscribed area of redness up to 3 cm. or somewhat more in diameter around the point of injection of the toxin. There may be some swelling and tenderness. There is usually a smaller central area, 1 to 1.5 cm. in diameter, dark red in color, which slowly disappears leaving in some instances a definite circumscribed scaly area of brownish pigmentation, which persists from three to six weeks. The area around the point of injection of the control material on the other arm remains completely negative throughout. A positive Schick test indicates that the individual has less than 0.01 unit of antitoxin per ml. of blood serum and, therefore, has an insufficient quantity in the tissues to afford immediate protection against clinical attack of the disease. Such individuals are commonly classified as "susceptibles." Actually, they are susceptible to infection, but not necessarily to clinical attack. If infected, they may produce antitoxin in such quantities and with such rapidity as to neutralize the toxin liberated by the invading micro-organisms before it can give rise to manifest clinical symptoms.

If the test is *negative*, both arms remain without reaction of any sort. Antitoxin is present in sufficient amount to afford protection to an ordinary exposure to diphtheria. A negative Schick reaction indicates that the individual has 0.01 of a unit of antitoxin per ml. of blood serum or more. Such individuals are, therefore, classified as "immunes."

A *pseudoreaction* indicates some degree of hypersensitiveness to the proteins contained in the toxic broth filtrate. About the point of injection of both the test



and the control material there appears an area of erythema in 6 to 18 hours which reaches its height in from 36 to 48 hours, and fades at both sites alike to disappear completely within three to four days. This should be interpreted as a negative (immune) reaction. Such an individual possesses sufficient antitoxin to afford protection but, in addition, is allergic to some component of the injected material.

In a *combined reaction*, a red area appears on both arms but differs in intensity and persistence. Around the point of injection of the toxin the reaction passes through successive stages of a positive test persisting five to seven days or more. Reaction on the control arm follows the course described for the allergic type of response and disappears on the third or fourth day. Since there is evidence of insufficient toxin to afford protection, this must be interpreted as a positive reaction indicating some degree of susceptibility. However, the existence of allergy is interpreted as suggestive of previous contact with the diphtheria bacillus or its products and as evidence of at least a potential state of immunity.

The allergic manifestations seen in a combined reaction or a pseudoreaction are rarely seen in infants and become more frequent in older children and adults.

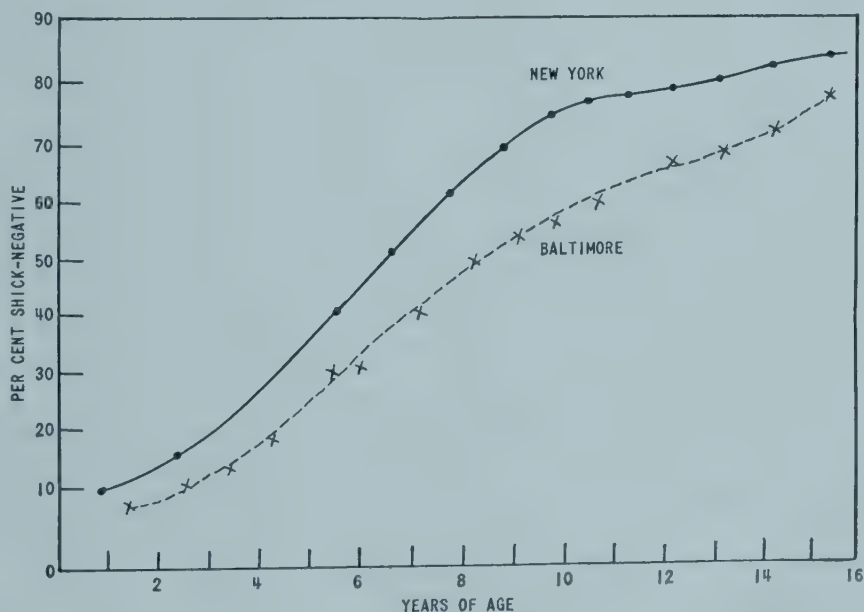
**Primary and Secondary Antigenic Stimuli.** In his critical review of the Schick test and its applications, Dudley (1929) pointed out that in order to interpret the reaction in its relation to immunity it is absolutely essential to grasp the concept of primary and secondary stimuli.

In 1921 and 1922, Glenny and his colleagues published work which showed that when a dose of diphtheria toxin-antitoxin mixture is given to an animal, which has never been inoculated before, and which has no diphtheria antitoxin in its blood, there is a latent period of about three weeks before any antitoxin can be detected in the animal's blood. Antitoxin then appears, and its quantity gradually increases to reach a maximum about eight weeks after inoculation. The antitoxin titer then slowly declines. This is the type of response to a primary sensitizing dose in an animal with no previous experience of the antigen employed. If, after all or nearly all of the antitoxin has disappeared from the blood of an animal which has had such a primary stimulus, a second injection of toxin-antitoxin mixture is given, antitoxin reappears in three days instead of three weeks, and the antitoxin titer reaches its maximum in about eight days instead of weeks. Moreover, the quantity of antitoxin produced is 10 to 100 times the amount produced by the original primary stimulus. An antigenic inoculation which produces this type of response is termed a secondary stimulus. Thus, in an organism that has been sensitized by an antigen, although no antibody may be present in the blood, yet the animal, as regards its immunity, is in quite a different state to one which is not so sensitized. Such a sensitized or experienced animal may respond to further antigenic inoculations, or secondary stimuli, even if of very much smaller intensity than the primary stimulus, by making antibody at 10 times the rate and 10 times as potent as an inexperienced animal. Glenny and his collaborators have demonstrated that these two types of response to primary and secondary stimuli are probably of general occurrence, and take place with many of the specific antigen-antibody reactions in the animal organism. The conception of primary and secondary stimuli is of fundamental importance in understanding the phenomena of immunity to infectious disease. It is also of great practical importance in vaccine therapy, as Glenny's researches have explained the necessity of correctly spacing curative and prophylactic injections if the best results are to be

obtained. Glenny (1925) has summarized his own, and other workers' views, which no one interested in the subject can afford to miss reading. The primary and secondary stimuli concept explains the fact that nearly all observers of any experience report that the few relapses from Schick negative to positive, which have occurred after active immunization against diphtheria, with few exceptions, have responded immediately to a single dose of diphtheria antigen, even though the original immunity had taken much time and trouble to produce. The first course of prophylactic injections had acted as a primary stimulus enabling a much less intense second course to act as a secondary stimulus. O'Brien, in 1926, showed that even the minute dose of diphtheria toxin contained in the Schick injection is often sufficient to induce a rise in the antitoxin titer of the blood from below to above the theoretical threshold between positive and negative reactions.

**Susceptibility and Immunity.** Utilizing Römer's technic, it has been established that during the first few months of life the infant is protected if the mother has acquired immunity. Antitoxin is transmitted to the fetus through the placental circulation and to the infant in the mother's milk. The immunity which the infant may possess during the early months is gradually lost unless it is exposed to natural infection. At the end of the first year approximately 80 to 90 per cent of infants are susceptible.

Application of the Schick test to population groups has afforded an invaluable means of studying the manner in which antitoxic immunity is acquired with advancing age (Dudley, 1929). Figure 1-9 (Frost, 1928) shows the percentages of



From Frost, W. H., J. Prev. Med., 11:325, 1928.

Fig. 1-9. Percentages of children found naturally Schick-negative in New York City and Baltimore.

children found naturally Schick negative in New York City and in Baltimore about 1920, when relatively few had been artificially immunized against diphtheria. The rate at which this antitoxic immunity is acquired with advancing age varies widely. It is determined primarily by living conditions and the level of endemic or epidemic



prevalence of diphtheria in the community (Dudley, 1932). It is further modified by the extent to which the population is subjected to artificial immunization.

Under conditions of exposure in the United States, about one third of persons reaching young adult life remain positive. The results of a Schick survey among 18,000 Naval recruits, carried out during the period from October, 1941 to January, 1942 (Worcester and Cheever, 1949), indicates the manner in which immunity status varies in different parts of the country. Recruits from the South Atlantic and East and West South Central States had the lowest frequency of positives, 15, 13 and 16 per cent, respectively. The percentages of positive reactions in other regions varied from 39 per cent in the Middle Atlantic States to 50 per cent in the West North Central area. Similar results were obtained in an immunity survey of military recruits in the United States conducted in 1951 (Liao, 1954).

It is notable that a considerable proportion of individuals go through life without having developed a negative Schick reaction. This is explained in part by the fact that a considerable proportion of the individuals who have a positive test have experienced a primary stimulus. If exposed to infection, they are capable of responding with rapid production of antitoxin sufficient to prevent the development of clinical symptoms. Another possible explanation is, that the immunity to diphtheria depends in part upon a more fundamental phenomenon than the presence of antitoxin in the blood stream, namely, tissue reactivity or ability of tissue cells to localize quickly and hold invading bacilli near the initial focus of infection. The existence of such an antibacterial immunity as part of the human defensive mechanism has been indicated by several studies (Frobisher and Parsons, 1950).

**Carriers and Subclinical Infections.** Diphtheria bacilli do not necessarily disappear from the area of localized infection on the mucous membrane of the nose, throat or elsewhere with the establishment of convalescence. In about 50 per cent of cases they can no longer be recovered in culture when the local lesion has healed. On the mucous membrane of the nose and throat they may persist for some weeks, about 12 per cent of convalescents being positive at the end of two months, about 2 per cent at the end of three months, and approximately 1 per cent continue to be bacilli carriers for an indefinite period. The persistence of these micro-organisms in the nose and throat is favored by excessive adenoid tissue. Children whose tonsils and adenoids have been removed are distinctly less liable to diphtheria than those who have not had this operation performed and, in similar manner, they are less likely to harbor the organism for long periods of time. Nasal diphtheria is particularly liable to be associated with the carrier state. There may be a persistent serosanguinous discharge which contains large numbers of diphtheria bacilli. Convalescent nasal carriers are, therefore, an important source of contagion in the spread of the disease.

The concept of the role of mild unrecognized subclinical or inapparent infections in the spread of infectious disease was first developed by Koch during his studies of cholera in Hamburg in 1893. At about the same time, Park and Beebe examined throat cultures from 48 apparently well sisters and brothers of patients with diphtheria and found 24 of them were harboring virulent diphtheria bacilli. These observations were confirmed and extended by many investigators. Various estimates were made of the frequency with which virulent carriers could be found among familial contacts of cases of diphtheria. For example, in a carefully conducted study in Baltimore, from 1921 to 1925, it was concluded that approximately 23 per cent

of familial contacts were carriers of diphtheria bacilli. This rate varied from 31 per cent in the age group 0-9 to 20 per cent in the age group 20 and over (Kusama and Doull, 1931).

In a similar manner, carrier surveys were made upon institutional, school, military and civil population groups, particularly during the course of outbreaks of diphtheria. For example, Frost (1928) shows in Table 1-5 the result of bacteriological examinations of white children age 5 to 9 years, inclusive, in Baltimore

Table 1-5. Results of bacteriological examinations of white children aged 5 to 9 years, inclusive, in Baltimore schools in three surveys, 1921-1922

Period of Survey	Number Examined	Demonstrated Carriers of Virulent B. Diphtheria	
		Number	Per Cent
November to December, 1921 . . . . .	701	22	3.14
February to March, 1922 . . . . .	722	19	2.63
May, 1922 . . . . .	985	15	1.52
Totals	2,408	56	2.32

From Frost, W. H., J. Prev. Med., 2:325, 1928.

schools in three surveys, 1921 to 1922. At this time approximately 2.3 per cent of the school children were shown to be carriers of virulent *C. diphtheriae*. It should be noted that the percentages given in such surveys represent the proportion of individuals found positive at any particular time by the technical methods employed. The carrier rate in a population group is not static but constantly changing. New individuals are constantly being infected or reinfected and infected individuals are becoming negative. A carrier rate must, therefore, be interpreted in dynamic terms. If 1.0 per cent of a population are found to be positive at any one time, and if the average duration of the carrier state is about two weeks, perhaps 10 to 20 per cent of that population will have harbored the organism during the course of the year.

These direct observations as to the frequency of subclinical or inapparent infections with diphtheria bacilli were supported and extended by the results of Schick surveys. In the Baltimore studies reported by Frost (1928) and his colleagues whereas more than 68 per cent of persons had acquired immunity to diphtheria as indicated by a negative Schick test at the age of 15, only 12 per cent gave a history of having had an attack of this disease, a ratio of 5.7 to 1.0. Frost pointed out that only 21.5 per cent of children in this area were Schick negative on reaching the age of five years. On this basis, he calculated that the children had been immunized at the average rate of 4.3 per cent per annum in the first five years of life; by the end of the tenth year the proportion of Schick negatives was increased to 52 per cent, which corresponds to an average immunization rate of 6.1 per cent per annum between 5 and 10 years and, similarly, the rate per annum between 10 and 15 years is 3.2 per cent. He contrasted these rates with the official morbidity rate for clinical diphtheria between 1920 and 1923 in the same population. The results are shown in Table 1-6. For the whole age group under 15 the ratio of 6.6 immunizations to



Table 1-6. Mean annual rates of (a) specific immunization and (b) diphtheria morbidity, in three age groups of white population in study area in Baltimore

Age Groups	Mean Annual Rates per 10,000		Ratio a:b
	Immunizations as Indicated by Schick Tests (a)	Clinical Diphtheria (b)	
Under 5 years	430	96	4.5:1
5 to 10 years	610	86	7.1:1
10 to 15 years	320	21	15.2:1
0 to 14 years	453	69	6.6:1

From Frost, W. H., J. Prev. Med., 2:325, 1928.

one case of the disease agrees roughly with estimates previously made. From the progressive increase in the size of the ratio of immunizations to clinical diphtheria, Frost concluded that with increasing age children suffering infection with the diphtheria bacillus are progressively likely to develop immunity rather than the disease. From these and other data, which cannot be extensively reviewed, it has become apparent that the establishment of successive infections and resultant specific immunization in diphtheria takes place for the most part below the level of unaided clinical observation, i.e., subclinical or latent immunization. The exact ratio of subclinical to clinical infections differs in different geographic areas and from time to time in the same area, and even in different groups in the same area. It is determined by the circumstances of exposure, virulence of the prevailing strains and other factors.

**Transmission.** Since *C. diphtheriae* is an obligate parasite of the human host the ultimate source of all infections is a case of clinical diphtheria, a convalescent carrier or a subclinical infection. The organisms ordinarily leave the human host in discharges from the mouth and nose, occasionally from lesions at other sites. The modes of transmission follow the pattern of the upper respiratory group of diseases in general. Transfer from an infected to a noninfected individual may occur rather directly by droplets or by contamination of articles and hands to mouth. Since the organisms survive for hours or even days in the external environment, transmission may be indirect by contaminated articles or by dust. The relative importance of transmission by droplet nuclei and dust particles is unknown. Since the diphtheria bacillus grows in milk without appreciably changing its flavor or appearance this has been the occasional medium of dissemination for epidemic outbreaks (see Milk, Chapter 22).

**Artificial Active Immunization.** Park and Schroder (1932) were the first to realize that by using the Schick test to determine the susceptibility of children and a retest to note the changes in reaction it was possible to study the immunizing effect of various preparations and procedures. Early studies were concerned with the value of toxin-antitoxin mixtures for this purpose. The general principle involved in the use of these preparations was that antitoxic immunity could be conferred without

undesirable local and constitutional reaction by the injection of small doses of toxin which had been almost but not quite neutralized by the amount of antitoxin added. As a result of human trials with preparations containing varying quantities of toxin, agreement was reached upon the most favorable dose of toxin to be used and upon methods of standardization. It was found that three doses of the standardized toxin-antitoxin mixture of 0.5, 1.0, and 1.0 ml., spaced about three weeks apart, would change about 75 per cent of the injected individuals from Schick-positive into Schick-negative reactors.

At the same time, certain disadvantages in the use of the material became apparent. The antitoxin used in the mixtures was obtained from immunized horses. Although the horse protein injected is small in amount, about .001 of an ml. per dose, there is danger of inducing sensitization or of anaphylactic shock in the previously sensitive person. This objection led manufacturers to substitute an antitoxin prepared by immunizing goats and sheep. A more serious objection is, that the mixtures are somewhat unstable. They must be kept in the refrigerator while not actually being used. On the other hand, if frozen, they either lose their immunizing properties and become totally inert or they become toxic. The increased toxicity is sufficient to produce unpleasant general and local reactions and may react unfavorably upon a campaign for diphtheria prevention. For these reasons, the use of toxin-antitoxin mixture has been largely given up. It is occasionally employed in older individuals who may be extremely sensitive to the amount of protein contained in toxoid.

*Diphtheria toxoid* was first used in immunizing human beings by Ramon of the Pasteur Institute in 1923. Ramon (1924, 1925) named his product "anatoxine" but English speaking countries have adopted the name "toxoid" to avoid confusion with antitoxin. *Fluid toxoid* or *formol toxoid* consists essentially of a filtrate of a toxic broth culture of diphtheria bacilli to which has been added from 0.3 to 0.5 per cent formalin, followed by incubation at 37° C until toxicity has practically disappeared. The antigenic constituents of the broth filtrate, beside the toxin or toxoid, are the proteins derived from the meat and peptone used in the broth (unless a synthetic medium is used) and the proteins derived from the diphtheria bacilli. It contains no serum of any kind and can, therefore, be given without fear of sensitizing to later therapeutic dose of serum. Toxoid is very stable; the expiration date is 18 months from the date of manufacture. Freezing does not seem to change it, and no physical or chemical treatment yet applied has succeeded in restoring any degree of toxicity. It is usually administered in three doses, 0.5 ml., 1.0 ml., and 1.0 ml., at intervals of three weeks. In more than 90 per cent of individuals this will convert a Schick-positive into a Schick-negative reaction.

Soon after toxoid was introduced into use it was discovered that its antigenicity could be increased by precipitation with alum potassium in a final concentration of 1.5 to 2 per cent. The resultant precipitate is twice washed and resuspended in a volume of saline such that the final product has a quantity of the antigen specified in standardization. Thus, a certain amount of the inert and perhaps objectionable material included in toxoid has been eliminated. This preparation, known as *alum-precipitated toxoid*, is usually given in two doses of 1.0 ml. each, spaced three weeks apart. The immunizing effect is approximately equivalent to that of three doses of



fluid toxoid, changing a positive to a negative Schick reaction in more than 90 per cent.

In children up to 7 or 10 years of age severe local and general reactions following the injection of fluid or alum-precipitated toxoid are infrequent; in older children and adults this risk is increased. In a recent study Pappenheimer and others (1950) reported that the administration of fluid or alum-precipitated toxoid to an adult population was attended with a significant number of untoward reactions, some of which can be remarkably severe, as has been observed in the U. S. Army, and frequently elsewhere. Disability rates from such inoculations may run as high as 15 per cent. They found that nearly all of the severe systemic and local reactions occurred in Schick-negative individuals. There was a close correlation between intradermal reactions to the Schick control (pseudoreactions) and local or systemic reactions to subcutaneous injection of toxoid. In the groups that received purified material there was a significant reduction in the total number of such reactions.

All grades of reactions are seen, from local swelling and tenderness to severe illness with high fever and complete incapacitation lasting for two or three days. Pappenheimer and Lawrence (1948) showed that human subjects may be separately sensitive to either toxoid or bacterial protein or to both. Accordingly, it is good practice to do a preliminary skin test. This test may be carried out alone or as a control for the Schick test. One-tenth milliliter of toxoid diluted 1:10 or 1:20 is inoculated intracutaneously (Moloney test). A local area of redness at the site of the inoculation of more than 1 cm. in diameter disappearing within three days is interpreted as a positive reaction and indicates that the individual may give a local or general reaction to toxoid. These sensitive persons may receive toxoid in smaller doses, the first dose ranging from 0.2 to 0.5 ml. in 1:20 dilution depending upon the degree of reaction to the intracutaneous test. Subsequent doses may be given at intervals of two weeks and may be doubled if the local reaction from the preceding dose was not more than 3 cm. in diameter.

It has been found that diphtheria toxoid can be combined with other antigens to advantage (Volk, 1949). For example, Bell (1948) reported that the use of a mixture of alum-precipitated diphtheria toxoid and pertussis vaccine, given to young children in two doses, with a four-week interval, resulted in better protection against diphtheria as measured by the Schick test than that which would result from the similar use of ordinary unmixed alum-precipitated diphtheria toxoid. The combination of diphtheria toxoid, tetanus toxoid and pertussis vaccine has also been found to be effective (McComb and Trafton, 1950).

**Artificial Passive Immunization.** Before a satisfactory method of active immunization had been developed, prophylactic passive immunization was commonly used to confer temporary protection on exposed individuals. The usual prophylactic dose of diphtheria antitoxin is 1,000 to 1,500 units for an adult and 750 to 1,000 units for children. Schick recommended 50 units per kilogram of body weight. The protection thus afforded cannot be depended upon for more than two to three weeks. The advantage of passive immunity is that it is prompt. The disadvantage is that it lasts a brief time and produces a serum reaction. Death from anaphylaxis has occasionally occurred from its use. Doull and Sandidge (1924) estimated the risk to be of the order of one death among 75,000 persons receiving antitoxin. The adminis-

tration of diphtheria antitoxin prophylactically still has a place in selected situations, particularly in family practice.

**Active Immunization in the Presence of Antitoxin.** It has long been recognized that the passive transfer of maternal immunity to the newborn infant interfered to some extent with neonatal active immunization up to the time that antitoxic immunity was lost, toward the end of the first half year of life. Cooke (1948) brought evidence to confirm this concept by administration of combined diphtheria and tetanus toxoid to 284 infants, demonstrating a good response to diphtheria toxoid in infants lacking maternally transferred antibodies to diphtheria, and relatively poor response in young infants inheriting passive immunity. These results suggest that dependence cannot be placed on neonatal immunization of infants against diphtheria. However, the use of an antigen potentiated by an admixture with adjuvants or combined with other antigens, such as pertussis bacilli, may overcome the handicap. Bell (1948) found that 201 infants from two to five months of age who received alum-precipitated toxoid combined with pertussis vaccine showed essentially the same Schick negative rate a year later, as was found in 236 older infants given alum-precipitated toxoid alone.

These results suggest that in presumably susceptible children up to the third or fourth year of life, who have been exposed to infection, it may be desirable to employ both active and passive immunization. The administration of a prophylactic dose of antitoxin may be followed about a week later by the injection of a dose of fluid or alum-precipitated toxoid. Simultaneous active and passive immunization for the protection of infants and young children has been advocated by a number of observers. Phair and Root (1942), on the basis of animal experiments, concluded that the simultaneous administration of a prophylactic dose of antitoxin and an immunizing injection of alum-precipitated toxoid, under appropriate conditions, was justified in prevention of diphtheria in such susceptible contacts of known cases.

**Prevalence.** In the first half of the nineteenth century, diphtheria was endemic in Europe and the United States, apparently also in many other countries. From 1800 to 1850 more or less localized epidemics of malignant diphtheria were occurring from time to time, especially in France. Between 1850 and 1860 there developed, apparently from a focus in France, a great pandemic, within a decade spreading over the world. In Western Europe and the United States, the regions for which we have the best records, diphtheria became much more prevalent and much more malignant, insomuch that practitioners of the day often spoke of it as a "new" disease. Its mortality rose to extraordinary heights, which with considerable fluctuations was sustained for 25 to 30 years, i.e., until about 1885 or later when a consistent decline began.

The data in Figure 1-10 showing the case fatality, morbidity and mortality rates from diphtheria, in three states during 40 to 100 years, is representative of the general trend in the United States. The downward trend in the death rate began before antitoxin came into general use, which was about the turn of the century. A considerable part of the decrease in the case fatality rate which is apparent between 1900 and 1920 can be attributed to the use of antitoxin and better medical care. During this same period there was little if any decrease in morbidity from diphtheria as indicated by the rate based on reported cases. There is much evidence



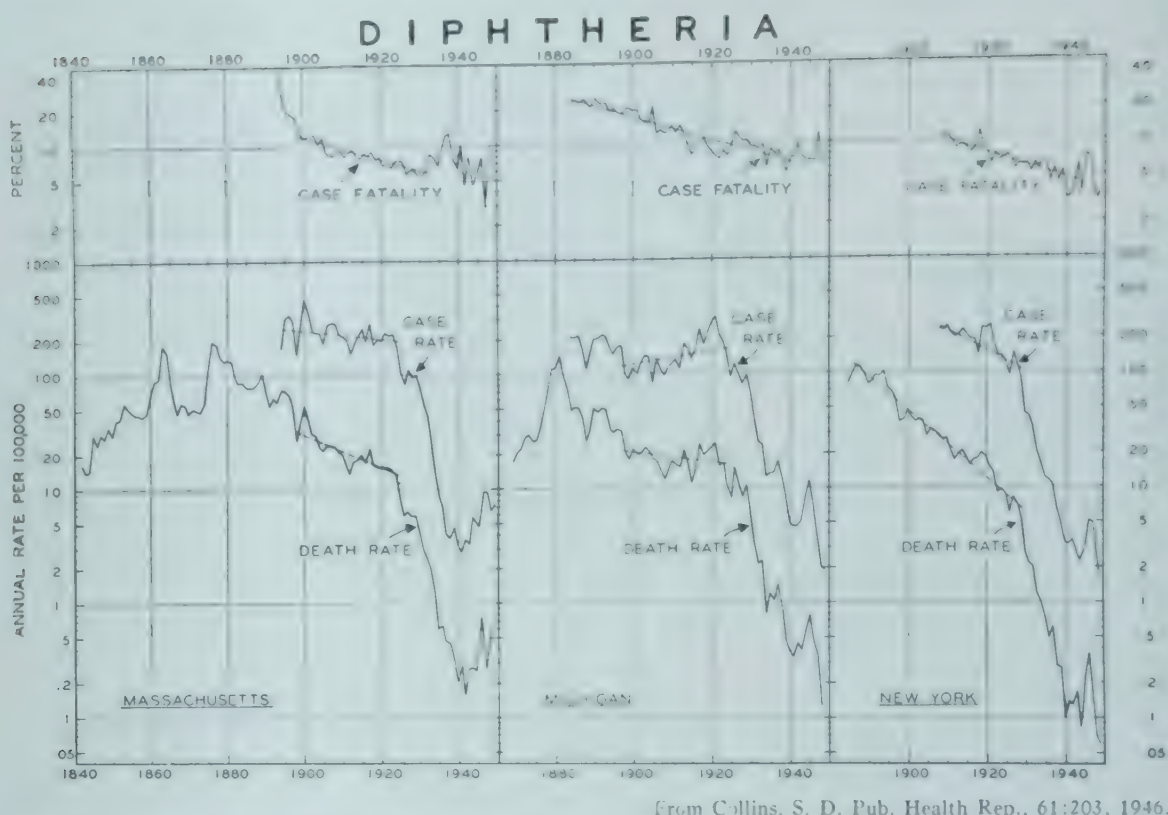


Fig. 1-10. Trend of diphtheria incidence, mortality and case fatality in three states during 40 to 100 years ending in 1944 for deaths and 1945 (provisional) for cases.

to indicate that the abrupt drop in morbidity which began about 1928 was related to the increasing and widespread use of active immunization.

The same downward trend that was observed in North America up to 1925 was noted in many European countries. In some of these countries it was sustained up to the outbreak of World War II. However, in other countries, as in England and Wales and Scotland, it levelled off after World War I and in Germany it began to rise during the middle thirties. Shortly after the outbreak of World War II, an epidemic wave swept over most of Europe, affecting those countries particularly in which very little active immunization had been practiced. Manifestations of this recent pandemic of diphtheria have been described by Stowman (1946). In the United States this wave was apparently reflected by interruption in the previous rate of decline and a slight rise in incidence in 1944 and 1945, due principally to marked increases in the south and southwestern states. Since that time the decline has been resumed. The incidence of the disease has been reduced to the vanishing point in the northern states (Anderson, 1947), but the disease still persists in the rural south.

One of the characteristics of the recent pandemic of diphtheria has been marked increase in the proportion or, indeed, often in actual numbers of adult cases. This shift appears to be due in part to the obvious fact that where extensive artificial immunization has been carried out among children any increase in diphtheria will be more likely to affect adults.

Aside from the effect of the use of antitoxin and improved medical treatment

to prevention of deaths and of mass immunization programs in the prevention of clinical cases, the cause or causes of the natural decline in diphtheria is largely a matter of speculation. However, it seems apparent that one of the principal factors is a decrease in the pathogenicity of the prevailing strains of diphtheria bacilli. The disease in the North Temperate Zone has taken on more of the characteristics of tropical diphtheria with a high ratio of subclinical or immunizing infections to clinical cases.

**Control.** With the advance in knowledge of the frequency of inapparent infections, carriers and missed cases, and the failure of technical methods to reveal all such infections, it has become clear that to prevent the dissemination of diphtheria bacilli in a community is a formidable task. Nevertheless, it is equally apparent that the occurrence of a clinical case of diphtheria in a family provides a focus from which dissemination may take place. It has been shown that the risk of a clinical attack was far greater for intrafamilial contacts of a case than for the contacts of a casual carrier in the population. Some measure of restriction of the movements of members of the family group invaded by diphtheria is, therefore, justified.

All suspected cases of diphtheria should be isolated pending confirmation of the diagnosis. The patient should be kept at bed rest for a minimum period of two weeks. At the end of this time cultures should be taken from the nose and throat before release. Two consecutive negative cultures, taken 24 hours apart, should be obtained before discharge. If any of the cultures are positive at this time the laboratory should be requested to ascertain whether or not the organisms are toxigenic. If diagnostic laboratory facilities are not available, isolation may be terminated at the end of two weeks with a fair degree of safety.

All familial contacts should be placed under medical surveillance and examined daily for evidence of infection. Cultures should be taken from the nose and throat for diphtheria bacilli. Although the probabilities are that the older children and adults in the family are immune as a result of previous experience, either natural or artificial, this assumption should be safeguarded by keeping them under observation. The exposed younger children and infants, unless known to be immune, should receive an immediate injection of alum-precipitated toxoid. If the child has been previously immunized, this will act as a secondary stimulus or booster dose; if not, it will give the child the advantage of a primary stimulus before a potential infection has had time to materialize. On account of the danger of laryngeal diphtheria, infants that are not known to have been previously immunized should receive a prophylactic dose of antitoxin. This may be given at the same time as the injection of alum-precipitated toxoid, but in that event a second injection of toxoid should be made within three weeks.

Familial contacts found to have positive nose or throat cultures should be restricted until negative cultures have been obtained. Children with positive cultures should be restricted from play with susceptible children or attendance at school until two negative cultures have been obtained. Adult carriers whose occupations involve the handling of food or close association with children should be excluded from these occupations until shown by bacteriological examinations to be negative. The persistence of the carrier state in some individuals continues to be an annoying problem in public health administration. The local application of various antiseptics such as sodium ricin oleate, gentian violet, iodine, and mercurochrome has been



tried with discouraging results. Exposure to ultraviolet and deep x-ray treatments have been to no avail. Tonsillectomy and adenoidectomy are the most effective methods of clearing up carriers. Before the operation the patient's Schick test must be negative.

When a case of diphtheria has occurred in a school, institutional, military, or other group, daily medical examination of intimate contacts of the patient should be made for at least a week after last exposure. Search for carriers in large groups by culturing nose and throat is ordinarily not a profitable undertaking. Prevention of further cases depends upon the proper application of immunization procedures to exposed susceptibles, indicated by the history of previous immunization or by the Schick test.

Isolation and quarantine restrictions directed by the occurrence of cases in families, schools, institutions or military organizations will not materially affect the spread of diphtheria bacilli through the population of a community. It has been well established, however, that the occurrence of clinical cases of diphtheria can be reduced to the vanishing point by an effective long range program of active immunization. The program must provide for the follow-up of all births to insure the beginning of the immunization by giving two doses of toxoid, one month apart, between the second and sixth month, and the giving of a recall dose within 3 to 12 months. Children should be given a second immunization, or at least a recall dose, before entering school. It may also be advisable under some circumstances to give a booster injection of 0.1 to 0.5 ml. of alum-precipitated toxoid (preferably purified in preparation) to older children and adolescents living in communities in which diphtheria has not been recently prevalent (James and others, 1951).

With such a program, even in the absence of natural exposure to *C. diphtheriae*, there is a progressive decrease in the proportion of the population which is susceptible in the course of time. However, under conditions of practical public health administration, it is seldom possible to extend protection to every individual in a community. Not only are there some who escape immunization procedures for one reason or another, but there is also a not inconsiderable proportion of individuals who are poor reactors to the specific antigen. A small outbreak of diphtheria occurred in Baltimore in 1944 (Eller and Frobisher, 1945) at a time when it was estimated that upwards of 75 per cent of the children had been given toxoid at some time during their lives. Among the 123 cases which occurred, there was a record that 45 per cent had previously received toxoid; in an additional 18 per cent there was a questionable history of having previously received one or more injections of some form of diphtheria immunizing material. Similarly, Mattison (1944) investigated an outbreak in Kingston, New York, in which there were 28 cases. Eighteen were reported to have been previously immunized; 23 were among children of school age. It was estimated at the time that 75 per cent of the children of school age and 44 per cent of preschool children had received artificial immunization.

**Disinfection.** Disinfection has a place in controlling this infection in the home. The necessary measures to be taken during the course of the illness and at the termination of the isolation period should be carried out in accordance with instructions from a public health nurse.

A special cleansing with soap and water of floors, walls, door knobs, bed frames and other surfaces that have been contaminated will suffice.

**Prevention of Postdiphtheritic Paralysis.** It has been observed that postdiphtheritic paralysis is more frequent since the use of antitoxin than before the days of serum therapy. This is due to the fact that many cases now recover that would formerly have died. It is also due to the fact that diphtheria antitoxin is sometimes used too late. The prevention of postdiphtheritic paralysis, therefore, consists in giving *sufficient* amounts of antitoxin *early* in the disease. The antitoxin does not influence the paralysis after it has once appeared.

**Responsibility for Diphtheria Deaths.** People still die of diphtheria—usually because the diagnosis is not made early and because diphtheria antitoxin is not given in time.

Diphtheria antitoxin is a specific and sovereign remedy when given in sufficient amounts during the first 24 hours of the disease. Upon the first appearance of sore throat, fever, or other suggestive symptoms in persons who are exposed to diphtheria, and without waiting for bacteriological confirmation, a full dose of 3,000 to 10,000 units or more in proportion to weight should be administered without delay. It is absorbed more quickly when given *intramuscularly*. In very toxic cases, or for late use, it acts most quickly when given intravenously. In order to obtain the full lifesaving benefits of diphtheria antitoxin, it must be given early in the disease. Time is the most important factor (Stevens, 1931). When the damage to the cells has been done, it may be too late.

In a study of 1,000 deaths made by Carey (1919) of the Massachusetts State Department of Public Health, it is shown that the useful knowledge and facilities of dealing with diphtheria are utilized far too little. In 23.1 per cent of the cases, the patient was ill a week before the physician was called. In 4.2 per cent, the patients had been ill from one to two weeks before they received attention. In 7.6 per cent of the deaths, the disease was not recognized during life. In a number of fatal cases, the physician delayed antitoxin treatment by waiting for laboratory confirmation of the diagnosis. In not a single instance was the antitoxin given intravenously. A similar situation was found in New York City—"with a diagnostic laboratory service unsurpassed, with Schick test outfits, antitoxin serum, and active immunization outfits practically at their elbow, the physicians of New York were charged with insufficient or delayed utilization of these aids and with responsibility of continued prevalence of fatal cases of diphtheria." Every death from diphtheria should be

Table 1-7. Amount of antitoxin in the treatment of a case of diphtheria

	Mild Cases Units	Moderate and Early Severe Units *	Severe and Malignant Units *
Infants, 10 to 30 lbs. in weight under 2 years	3,000 to 5,000	5,000 to 10,000	7,500 to 10,000
Children, 30 to 90 lbs. in weight under 15 years	4,000 to 10,000	10,000 to 15,000	10,000 to 20,000
Adults, 90 lbs. and over in weight	5,000 to 10,000	10,000 to 20,000	20,000 to 50,000
Method of administration advised	Intramuscular	Intravenous	Intravenous

\* When given intramuscularly use the larger amounts indicated.



investigated and the responsible party brought to task. The facts indicate the further need of education of both the profession and the public, in order to save lives from this and other preventable infections.

#### PREVENTION OF SERUM SICKNESS AND ANAPHYLACTIC SHOCK

Serum sickness is a syndrome which frequently follows the injection of horse serum into man. The symptoms usually come on about 8 or 10 days following the injection. The period of incubation is shorter if the person has had a previous injection of homologous serum. The syndrome consists of various skin eruptions, usually urticarial or erythematous in character; also fever, vomiting, edema, glandular and splenic enlargements, rheumatic-like pains in the joints and muscles and albuminuria. The eruptions may be either local or general, and sometimes resemble those of scarlet fever or measles. Serum sickness has nothing to do with the antitoxin, but is caused entirely by the foreign proteins contained in the horse serum. It may be produced with normal horse serum as well as with antitoxic horse serum, and is explained in terms of allergy. The occurrence and severity of the symptoms depend upon the amount of foreign protein injected and the sensitiveness of the individual. If concentrated antitoxic serum is used, the reactions are correspondingly lessened because smaller quantities of the foreign protein are injected, the albumins and certain other proteins having been eliminated by the partial purification. The concentrated antitoxin contains mainly serum-globulin.

Under certain circumstances, however, anaphylactic shock develops a few moments after the injection and may be fatal. H. F. Gillette collected 28 cases of collapse after serum injection, of which 15 died. Rosenau and Anderson brought together some 19 cases of sudden death following the injection of horse serum. This unusual and serious complication comes on within a few minutes of the injection, and is characterized by collapse, unconsciousness, cyanosis, labored respiration and edema. The heart continues to beat after respiration has ceased. The entire picture is an exact counterpart of the anaphylactic shock so readily produced by a second injection of horse serum in the sensitized guinea pig.

Contrary to the experimental work on serum anaphylaxis in the lower animals, the cases of sudden death in man usually follow the first injection of horse serum. Just how man becomes sensitized in these cases is not always clear. It may be by a previous injection of horse serum, or by eating horse meat, or by the introduction of small amounts of horse protein through wounds of the skin or through the respiratory tract; or hereditary transmission may account for the susceptibility.

Most cases of anaphylactic shock occur in healthy persons who give a history of asthma or discomfort when about horses. This is a practical and important point, and should be inquired into before horse serum of any kind is injected. Horse serum should not be injected into such individuals unless the indications are clear and then only with a statement as to the possible outcome. Desensitization may be tried or bovine serum substituted.

**Desensitization.** It is a question whether it is possible readily to desensitize man in a short time. In case hypersensitiveness is suspected, spaced injections of serum beginning with very small amounts subcutaneously may be tried. Hypersensitiveness may be inferred from an ocular or intradermal injection. There is, however, no

necessary correlation between local hypersensitiveness and general anaphylactic reactions.

Adrenalin is the best therapeutic agent to prevent and relieve serum allergy. Full therapeutic amounts should be used and this material in a syringe should be on hand ready for emergency use.

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### VINCENT'S ANGINA (FUSOSPIROCHETAL DISEASE)

(*Fusospirochetalosis*, *Plaut-Vincent Angina*, *Ulceromembranous Angina*)

Vincent's angina is an infection associated with spirochetes and fusiform bacilli. It is characterized by inflammatory lesions of the mucous membrane, usually of the mouth. It remains on the surface, not affecting the membrane deeply. Its progress is slow and often chronic. Ulceration and pseudomembranous formation occur. If not the cause, it may be associated with the progress of pyorrhea alveolaris. The only local symptom may be pain and constitutional reaction may be absent. Sometimes there is moderate fever.

The name Plaut-Vincent disease is often given to this infection, after Plaut who described the organism in 1894 and Vincent in 1896. Leeuwenhoeck, the father of microscopy, doubtless saw the spiral micro-organisms with his crude lenses in 1683.

According to Smith (1932) the infection is caused by fusiform bacilli (*Borrelia buccale* and *Borrelia vincentii*) and spirochetes (*Treponema microdentium* and *Treponema mucosum*) acting in symbiosis with vibrios and cocci. The spirochetes and fusiform bacilli never appear alone in progressive lesions. They are normal inhabitants of the gums, but their numbers increase enormously when the local tissue resistance is reduced either by trauma or by deficiencies of certain vitamins, such as niacin and ascorbic acid.

The unsanitary conditions of military operations make fusospirochetal disease a war disease. It was prevalent during the American Civil War, the Franco-Prussian War, and the Spanish-American War. During World War I the disease prevailed in epidemic form and was called "trench mouth."

When the tonsils are involved because of the pseudomembrane, Vincent's angina is confused with diphtheria. The diagnosis is made by microscopic examination of stained smears. The yellowish gray membranous exudate is easily removed, leaving a raw bleeding surface. There may be a rapid ulceration of the tonsillar tissue resulting in a deep "punched out" ulcer which has sometimes been erroneously diagnosed as syphilitic.

Regions remote from the mouth and pharynx are often attacked. The more comprehensive term, fusospirochilosis, therefore is favored on account of the wide distribution of the lesions. There is a related group of infections characterized by necrosis and destruction of tissue, pseudomembranous formation in superficial lesions and a fetid odor, which occur not only in the tonsils, gums, cheeks, tongue, pharynx and larynx, but also in the eyes, ears, trachea, bronchi, lungs, esophagus, appendix, colon, and genitalia. Lesions even occur in the brain and other organs when the infection is carried internally as emboli in the blood stream. Members of this group of spiral organisms are responsible for such diseases as noma, the bronchial spirochetosis of Castellani, and fusopirochetal pulmonary gangrene and abscess (Smith, 1932), tropical ulcer, and pseudomembranous and phagedenic infections of the male and female genitalia.

**Prevention.** Vincent's angina is more often found in those who have unclean mouths, faulty fillings and other sources of irritation. Those who practice oral hygiene may also become infected. The infection is spread mainly directly, but occasionally indirectly. Eating utensils, towels, drinking cups, personal articles, and kissing are all operative. The infection is apt to spread among those who live, work and play together.

The first principle of prevention is to keep the mouth in a clean healthy condition. No decayed teeth or broken down roots should be allowed to remain. The mouth should be thoroughly cleansed by the use of a tooth brush and dental preparation (soap or salt water is more serviceable than many expensive dentifrices). Household remedies which are useful both in the prevention and treatment of Vincent's angina are hydrogen peroxide (equal parts), potassium permanganate (1:5,000), and one of the pleasant sodium perborate preparations. All these when freshly prepared liberate oxygen and theoretically are best for this anaerobic infection. The gums should be properly massaged with a tooth brush or the finger. It is possible for a clean mouth to become infected, but healthy vigorous gums and mucous membrane are resistant.

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### WHOOPING COUGH

(*Pertussis*)

JOSEPH A. BELL, M.D., DR.P.H.

Whooping cough is a communicable disease caused by infection with *Hemophilus pertussis* (Bordet-Gengou bacillus) and characterized by catarrh of the respiratory tract with paroxysmal cough frequently ending in whooping and vomiting. The long drawn-out course of the disease is distressing and interferes with nutrition and rest. A fatal bronchopneumonia is not uncommon, especially in infants. The infant mortality rates reported for whooping cough have generally exceeded those of other common communicable diseases but have dropped precipitously during the past few years.

Epidemic whooping cough was first described by Baillou of Paris in 1578. In 1906 Bordet and Gengou isolated and described the causative agent of the disease.



Even then interest in the disease was thin. The vigorous attack which served to solve so many other problems in preventive medicine was lacking for a long time.

Willis, in 1674, said, "Whooping cough is left to the management of old women and empirics" and such is still largely the case. The attitude of indifference with which the general public regards whooping cough contrasts strangely with the fact that it is one of the most distressing and fatal of the acute infections of childhood. Up to recent years the lack of specific prophylactic and therapeutic agents contributed to this attitude of indifference.

**The Disease.** The incubation period of whooping cough is usually 7 to 10 days, but it may possibly range from 4 to 16 days.

The onset is insidious and in many instances the patient appears to develop a cold. The typical clinical course may be described in three stages: (1) catarrhal, (2) paroxysmal, and (3) decline. The catarrhal stage lasts about 10 days. During this time if there is cough without other physical signs, and leukocytosis with a relative lymphocytosis, whooping cough may be suspected and the diagnosis confirmed bacteriologically. Not until the paroxysmal stage, which usually comes on two to four weeks after exposure, can the disease be recognized clinically with any certainty. The paroxysm consists of a repeated series of explosive coughs in rapid succession without opportunity for inspiration, ending with a long inspiratory whoop. The violence of the coughing spasm may be necessary to raise typical, very tenacious mucus. The stress causes cyanosis, the face is livid, and the strain often ends with vomiting and occasionally nosebleed. The paroxysm is distressing and leaves the child exhausted. Nutrition suffers and complications are invited. The number and severity of paroxysms vary greatly. Whoop may be absent in mild cases and especially in adults and infants. The second stage lasts four to six weeks, passing gradually into the stage of decline, when attacks become less frequent and finally disappear. Paroxysms sometimes recur six months or more after recovery, in the event of a respiratory infection.

**Occurrence.** Pertussis is a common disease of childhood; it occurs throughout the world and at any season of the year. Susceptible children are constantly being born into the population, and in areas where such susceptibles have sufficient contact to permit a continuous chain of new infections, the disease remains endemic. In smaller, more isolated areas where a continuous chain of susceptibles is not available, the disease cannot maintain itself and it disappears, sometimes for a period of years; later, when it is reintroduced to the area, a large number of susceptibles has accumulated and an epidemic often results. In the relatively isolated Faroe Islands, Madsen reported a large epidemic about every seven years. In general, however, aside from a slight but definite seasonal variation, regular recurrences of pertussis are hardly discernible. The seasonal variation of pertussis is strikingly small. The ratio of the number of cases at the peak and trough is 2:1 to 3:1, whereas for measles and other common communicable diseases the ratio may be 50 or more to 1. In the United States, the seasonal peak is in late March or early April, with the trough in October. In general, the reporting of cases of pertussis is very poor, and this is also true in the United States. The disease is definitely one of childhood with comparatively few cases occurring after the age of 12. Most cases occur in the age group 1 to 8 years, and in this age group the young cases are frequently the result of secondary contact in the family household.

Although the occurrence of cases by sex is almost equal, the sex distribution of pertussis mortality is unique among the infectious diseases. Females more often die from pertussis than males. This peculiar sex difference appears to be true for all ages, races and climates, and has existed for many years.

Mortality in pertussis is more completely reported than morbidity. The accuracy with which the actual cause of death is reflected by mortality reports needs a little elaboration. For example, in 1940 the U. S. Mortality Reports show 2,926 deaths from pertussis, and in 77 per cent of these influenza or pneumonia was listed as the secondary cause of death. In addition, there were 115 reported deaths from other causes where pertussis was listed as the secondary cause. There is a divergence of opinion as to whether pertussis mortality is under or over reported but in either event the proportionate error is probably small.

The age distribution of deaths is striking when contrasted with the age distribution of cases. The over-all case fatality at all ages is less than 1.0 per cent, and the case fatality is even lower in late childhood but high in infancy. Ninety per cent of the deaths occur before the third birthday and more than 70 per cent before the first. Actually, more deaths are reported due to pertussis during the second month of life than during any other month. The infant deaths from pertussis are generally higher than those from measles, diphtheria, scarlet fever, poliomyelitis or tuberculosis. The public health hazards of the disease are not to be measured exclusively by the number of deaths. The age of death is extremely important. When deaths in children are prevented with no resultant disability many person-years of productive life are gained, but when deaths at middle age are prevented only a few person-years of productive life are gained. In addition to the hazard from death the long, drawn-out, and distressing course of the disease causes considerable anxiety, suffering, inconvenience, and disability.

The death rate from whooping cough is much higher in Latin America than in the United States. Within this country during the years 1941 to 1945 the highest death rates were reported in the East South Central States (Kentucky, Tennessee, Alabama and Mississippi), and the lowest rates in the Pacific and New England States. In the Northern and Central States the peak of whooping cough mortality is in March and April, with a tendency to a slight rise again in July and August. In the Southern States the peak of mortality is in June and July.

The race distribution of deaths is interesting. The reported Negro death rates are two to three times the rates for whites and the Indian rates are eight times as high. The population base for the latter is known to be inaccurate. The higher Negro death rates may possibly be due to the urban-rural and age distribution of cases and possibly to inadequate medical care. The rural death rates from pertussis are generally higher than the urban rates. Luttinger (1917) found that 160 out of 162 consecutively reported deaths from pertussis had occurred in children living in tenements of New York City, and in over one half of the cases the mother worked away from home every day, and the average number of rooms occupied by the family of five or over was less than two and one-fourth. In addition, he found a death rate of 4.3 per cent in 161 cases investigated from tenements as compared with no deaths among 182 cases in private practice, including cases with illness and complicating bronchopneumonia.

There has been a downward trend in the rates for pertussis mortality in the



United States for many years. For example, the median crude rates per 100,000 population for each 5-year period from 1916 to 1950 were: 10.5, 8.1, 6.2, 3.9, 2.3, 1.9 and 0.4. The infant mortality rates per 1,000 live births follow a similar trend: 2.4, 2.1, 1.9, 1.4, 0.9, 0.6 and 0.2. Proportionately the decline has been dramatic in recent years. Much of this can be attributed to vaccines and specific therapy for complications, and further declines are anticipated as more effective vaccines and specific therapy, both for complications and for the disease itself, are more widely used.

**Etiology.** The Bordet-Gengou bacillus (*Hemophilus pertussis*) was isolated and described in 1906. The experiments of Rich and others (1932) on chimpanzees offer evidence of the specific role of the Bordet-Gengou bacillus in the etiology of pertussis. Three animals which received filtrate of sputum from pertussis patients developed only typical colds in five to seven days. Animals receiving unfiltered sputum also developed a cold, after recovery from which catarrhal symptoms appeared, and these in turn were followed by spasmodic cough accompanied by leukocytosis and relative lymphocytosis. Cough plates were all positive for *H. pertussis*, and pure cultures caused catarrhal symptoms followed by cough when introduced into normal chimpanzees. In addition, the blood of animals developing symptoms from unfiltered sputum or cultures showed complement-fixing antibodies for the Bordet-Gengou bacillus (MacDonald and MacDonald, 1933).

The present belief that the Bordet-Gengou bacillus is the cause of pertussis is based on: (1) the occurrence of the specific complement-fixing antibodies described by the original workers and since repeatedly confirmed, (2) the demonstration of the bacilli by cough plate or nasopharyngeal culture in 75 to 95 per cent of cases early in the disease, (3) uniform failure to find the organism apart from the clinical disease and those intimately exposed, (4) results of experiments on monkeys, (5) the experimental human transmission of the disease, and (6) the selective prevention and amelioration of symptoms through specific vaccine prophylaxis.

**Bacteriological Diagnosis.** The cough plate method was suggested by Mauritzen and was first used extensively by the Danish Serum Institute. The nasopharyngeal swab method is more practical and thus more efficient for bacteriological diagnosis. It consists of swabbing the nasopharynx by passing a fine copper wire, tipped with a small amount of cotton, through the nose. The culture medium is essentially that described by Bordet-Gengou and consists of ground potato with glycerin, agar, and 20 to 30 per cent blood. Selective bacteriostatics such as penicillin 0.2-0.3 unit per ml. assist in preventing overgrowth by other organisms. The plates should be freshly made and preferably not over one week old. The plates must be incubated for at least three to four days because the colonies develop slowly. They are hemolytic and small, smooth and raised, and resemble a particle of quicksilver. The organisms are identified as very short Gram-negative rods which agglutinate with the specific antiserum. Care must be taken to distinguish them from *H. influenzae* and parapertussis. The latter was described by Kendrick as an antigenically different organism causing symptoms similar to pertussis.

**Transmission.** Whooping cough is one of the more readily communicable of the group of respiratory diseases. The infective agent is carried in the secretions of the upper respiratory tract. It is spread by human contact including droplet infection and contaminated fomites.

Whooping cough is most communicable during the catarrhal and early paroxysmal stage. The disease may be transmitted during the latter part of the period of incubation, for the Bordet-Gengou bacillus has been found a few days before the start of the catarrhal stage. Infectivity wanes as the paroxysmal stage wears on. Using the now obsolete cough plate method for bacteriological diagnosis, the percentages of *H. pertussis* isolations at various stages of the disease are shown in Table 1-8. These figures were reported by Kristensen (1933) from the Danish Serum Institute, Copenhagen, which include Madsen's figures (1925). Using the newer nasopharyngeal swab technic the percentages of *H. pertussis* isolation at various stages of disease have the same general trend but are much higher and approximate 90 per cent.

These facts have been confirmed by many, although the actual percentage of positives found at the various stages varies. All observers note a sudden drop of organisms between the fourth and fifth weeks of the paroxysmal stage, and then a rapid disappearance. Madsen states that in Denmark children with negative cough plates are returned to school after the fourth week, though still whooping. The period of greatest communicability corresponds to the period when large numbers of pertussis colonies are recoverable by culture.

Healthy *carriers*, in the exact sense of the word, are unknown in spite of many attempts to demonstrate them bacteriologically. On the other hand, adults who have previously had the disease are apt, when exposed to pertussis, to contract a cold with cough lasting a few weeks. This is really a mild second attack of whooping cough, for the specific micro-organisms have been demonstrated repeatedly. Furthermore, epidemiologic investigators have traced infections in children to just such mild and missed cases in adults. These missed cases constitute a very small proportion of the total cases of whooping cough.

Table 1-8. Results from examination of 2,144 pertussis patients at the Danish Serum Institute

	Number of Pertussis Patients	Number of Patients with Bordet-Gengou Bacillus	Per Cent of Positive Bacillary Results
Catarrhal stage	378	247	65.3
Convulsive stage, 1st week	837	486	58.1
Convulsive stage, 2nd week	441	231	52.4
Convulsive stage, 3rd week	210	84	40.0
Convulsive stage, 4th week	104	35	33.7
Convulsive stage after 4th week	174	13	7.5

**Immunity.** Whooping cough at one time or another affects almost every member of a community; by the time adult age is reached, about 78 per cent have had a recognized attack. This percentage is being rapidly reduced due to a more extensive use of effective vaccines. The greatest incidence apparently is between six months and five years of age. Very few cases occur during the first few months of life, but the largest number of deaths occur at this young age. After five years the severity decreases with age. One attack confers a definite, prolonged, but not always complete immunity.

*Second attacks* take the mild form mentioned above and are of little significance to the individual. They are, on the other hand, of considerable epidemiological



interest, for bacteriological studies have shown them to be more common than formerly supposed.

**Specific Prophylactic Immunization.** During the past 40 years many attempts have been made to prepare and demonstrate the efficacy of prophylactic pertussis vaccines. The results of early studies were unconvincing mainly on account of inadequate epidemiologic controls. In addition, some of the vaccines have been nonantigenic. In 1931, Leslie and Gardner classified cultures into four antigenic types. Old cultures fell into types III and IV and were rough, avirulent, and antigenically ineffective. Thus, an experimental basis was established for the empirically known fact that only fresh preparations of recently isolated, "smooth" strains should be used for bacterial vaccines. Using fresh isolated cultures, the vaccine reports of Madsen in Denmark and Sauer in the United States and others were encouraging. The controlled studies of Kendrick and others indicated that the vaccine they used gave definite protection, but the carefully controlled studies of Doull and others showed no prophylactic value to the vaccine they used. Since 1938, many studies in the United States have adequately demonstrated that various vaccines have definite prophylactic value. The studies in England, however, showed that their vaccines had no value until the 1951 report of an excellent and extensive study using various vaccine products. All vaccines used gave substantial protection but one was much better than the others. The best vaccine gave very good animal protection. In 1947, Kendrick described a mouse protection test which has been developed to permit comparison of the mouse protective potency of various pertussis vaccines in a standardized manner. Vaccine products sold under license of the U. S. Public Health Service are now standardized in mouse protective units not significantly different from a reference standard. The hope is entertained that this will eliminate many of the possibly ineffective vaccines in the United States. It is generally thought that the mouse protection test when properly carried out under standardized conditions is a good index of vaccine antigenicity for humans.

In 1938 Harrison and others introduced alum-precipitated pertussis vaccine with the hope that two doses would give substantial protection and be practical for general public health use. In 1941, Bell showed that two small doses, a total of only 20 thousand million organisms, of an alum-precipitated product gave substantial protection against clinical attacks of pertussis even when given to children as young as two months of age. This opened the door for the general use of pertussis vaccine mixed with alum-precipitated diphtheria toxoid. Many reports confirm the value of such a mixture. In one intensive study, two small doses of the mixed product given with a month's interval between doses not only gave substantial protection against clinical pertussis, even when given at two months of age, but also gave better protection against diphtheria, as measured by Schick tests performed one year after immunization, than the same quantity of alum-precipitated diphtheria toxoid alone. Actually, the protection against diphtheria was as good when the mixed product was used at two months of age as when the unmixed product was used at six months of age. Most investigators of clinical protection, when using the fluid product, have used a total of 70 to 120 thousand million organisms in three to five doses at intervals of two weeks. With the alum-precipitated product, a total of 20 to 45 thousand million organisms have been used effectively in two or three doses with a month's interval between doses. In the United States the vaccine is now standardized to contain 12 mouse protective units per immunizing dose.

There are so many possible variables in the occurrence and recognition of clinical pertussis, and in various vaccine products and their method of use that it is difficult to assess accurately and quantitatively the prophylactic value of pertussis vaccines. In general, 80 per cent of young susceptible children develop a clinical attack following family household exposure to the disease, whereas only 10 to 30 per cent of vaccinated but otherwise similar children, develop a clinical attack following such exposure. It is likely that still greater prevention results in less intense and less prolonged exposure. All in all, in such a prevalent disease, cases are not uncommon in vaccinated children. Nearly all investigators agree that the vast majority of such cases are extremely mild. This clinical impression has been substantiated by careful and direct epidemiologic study. In the United States, the average annual urban attack rate of pertussis in young susceptible preschool children kept under surveillance for the occurrence of the disease generally ranges from 8 to 12 per cent. The attack rate in similar, but vaccinated children, depends upon many variables and is generally reported to range from less than 1 to 3 or 4 per cent. The usual incidence of cases reported to health departments is much lower on account of incomplete reporting. In 1945, Garvin reported that beginning in 1936 approximately 75 per cent of preschool children in Shaker Heights, a community of 25,000 people, had been given pertussis vaccine, whereas only a small per cent of such children in the nearby large city of Cleveland, Ohio, had been immunized. For the seven years prior and since 1936, respectively, the reported average annual incidence of pertussis in children under five years of age per 100,000 population was 290 and 35 for Shaker Heights, and 187 and 160 for Cleveland. In addition, as stated above, there appears to be a more precipitous drop in pertussis mortality rates in the United States during the past several years when vaccines and better methods of treatment of complications have been more extensively used. During a period when the annual number of births has increased from two million to four million in the United States, the annual number of deaths from pertussis has decreased from around 10,000 to less than 500. All in all, pertussis vaccines are generally accepted for public health use in the United States, since they can be mixed with alum-precipitated diphtheria toxoid and given with little added inconvenience, and they result in substantial protection known to last for several years in a large proportion of children, with amelioration of the distressing clinical symptoms in most of those not completely protected. For many years the American Public Health Association has recommended that all children be immunized against smallpox and diphtheria and now the recommendations include pertussis vaccine.

Vaccines have been used for the treatment of children exposed to pertussis and the results have not been convincing, particularly because of the lack of acceptable epidemiologic controls. In general, the reported successes have largely been following the use of vaccine in children's institutions where one or more cases have been introduced. In such experiences the difficulty of obtaining adequate controls is obvious. Even if a good vaccine had no value when given after exposure, it might still be beneficial in such circumstances because many children would receive it prior to effective exposure; it would be very difficult for one or two cases to expose effectively all other children simultaneously in a sizable institution. How many days it takes for protective immunity to be established following vaccination is unknown; certainly it is established within a few months and perhaps less than one month.

**Specific Treatment.** A brief passive immunity may be conveyed to young chil-



dren by the administration of appropriate amounts of convalescent serum or similar agents. The risk of homologous serum jaundice from the use of human serum must be kept in mind. Immune serum may be used for treatment of severe cases or for prevention in young infants after exposure. Reports indicate that they are efficacious, but convincing proof for their widespread general use is not at hand.

Complications following secondary infection with pathogens should be treated with the sulfa drugs or antibiotics specific for such infection.

In animal experiments, streptomycin appears to have little specific effect on *H. pertussis* infection. As with serum, the clinical value is encouraging but not thoroughly convincing. Aureomycin is dramatically specific in curing mice infected with *H. pertussis*. Chloramphenicol and terramycin appear to have a similar action. Early reports on their clinical use are extremely encouraging. An unpublished report of Bell shows that after three or four days of aureomycin treatment in 100 cases the positive nasopharyngeal cultures were reduced from 80 to 20 per cent. When given early in the course of the disease, aureomycin, terramycin, and chloramphenicol appear to modify the severity and shorten the duration of illness. If this reflects a substantial reduction in the period of infectivity, the prompt recognition and treatment of cases, it will do much to ameliorate the hazards of pertussis.

**Prevention.** With our present knowledge, there is good opportunity to do much in the amelioration of the health hazards of pertussis. The practical difficulties of controlling the spread of infection are evident. During the long catarrhal stage of whooping cough, communicability is high, and diagnosis difficult. Many lives may be saved by simply delaying the age incidence. Infants can and should be protected. Education of the public to realization of the seriousness of the disease is necessary for success.

All susceptible children of preschool age, i.e., under five years, should be vaccinated against pertussis. Young infants living under conditions where the risk of exposure is great, those living in institutions and in households with older susceptible children should have active immunization started by the time they are two months of age, particularly if pertussis is then prevalent in the community. Other children should have immunization started by the time they are six months of age. An alum-precipitated mixture of pertussis vaccine and diphtheria toxoid can be used effectively for simultaneous immunization against both diseases. Tetanus toxoid may also be included. Reinforcing (booster) doses of pertussis vaccine may be advisable within a year and at two or three years of age.

*Early diagnosis and prompt reporting are essential.* When a case is reported it should be isolated. This, however, presents practical difficulties. It is not good for a child with whooping cough to remain confined for weeks; it is a handicap to deprive him of the benefits of sunshine, fresh air, and play. When the patient is permitted to be out-of-doors he must avoid contact with susceptible persons and not go to school, theater, church or public assembly, or ride in street cars or public vehicles. Children should go out only when accompanied by an intelligent caretaker as a protection to others.

Immediate investigation of contacts should be carried out, with especial attention to those under two years of age. Susceptibles should be placed under observation and a bacteriological diagnosis sought when early symptoms develop.

In whooping cough, even more than in most other acute infectious diseases, good

nursing and medical care are important, particularly for children under two years of age. Each community should provide adequate medical care for young children with pertussis, whose guardians cannot provide such care.

Laboratory facilities for bacteriological diagnosis should be provided.

After the paroxysms are established, communicability gradually decreases and becomes negligible for ordinary nonfamilial contacts in about three weeks, even though the sporadic cough with whoops may persist. The shortening of the quarantine period will promote cooperation of both laity and physicians by decreasing the hardship of isolation.

Schools need not be closed on account of whooping cough. Daily inspection of pupils when pertussis is prevalent may achieve better results. The patient should be separated from susceptible children and excluded from school and public places during the most communicable period of the disease, i.e., for 7 days after exposure to 21 days after onset of typical paroxysm. Susceptible children who are household contacts of a case should be similarly separated for two weeks after last contact but may be permitted to attend school if daily examination by a physician or a nurse finds them free from cough and catarrh. Other members of the household may be allowed to follow their usual occupations.

The chief measures for control of pertussis are prophylactic vaccination of all infants, protection of young children from exposure, and adequate medical care of cases.

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### MENINGOCOCCIC MENINGITIS

(*Epidemic Cerebrospinal Meningitis, Cerebrospinal Fever*)

Acute purulent cerebrospinal meningitis may be caused by any one of a number of pathogenic bacteria by extension of an infectious process, either directly or through the blood stream to the meninges. Epidemic cerebrospinal meningitis, or cerebrospinal fever, is caused by the meningococcus. The clinical characteristics of the disease were first described by Vieusseux in connection with an outbreak which occurred in Geneva, Switzerland, in 1805. It was not until 1887 that Weichselbaum established the relationship of the meningococcus (*Neisseria meningitidis*) to this disease. This led to more exact diagnosis and an understanding of its pathogenesis.

**The Disease.** There are three stages in the development of meningococcus infection: (a) localization in the nasopharynx, (b) invasion of the blood stream, (c) involvement of the meninges. The variation in the clinical pattern depends upon the rapidity of progression through these three phases and their duration. On the one hand are the cases in which the clinical picture is that of a sepsis with little or no



involvement of the meninges. The meningococcemia may be transient and recovery follow after a brief illness of protean character, or it may be persistent, lasting over several days or weeks. At the other extreme are the cases which pursue a fulminating course, the patient becoming stuporous, passing into coma and dying within four to eight hours. Of 216 cases reported during an epidemic in Memphis, Tennessee, in 1929, 37 died within 24 hours and 8 more within 48 hours. If the blood stream invasion is a marked feature, it is manifested by an irregularly distributed petechial, purpuric or maculopapular skin eruption. These vascular lesions are due to thrombo-embolic involvement of the capillaries. They occur in from 10 to 70 per cent of patients, the frequency varying somewhat with different epidemics. Because of this characteristic, such designations as "sinking typhus," "cerebral typhus," and "spotted fever" appeared in the early writings indicating confusion with typhus fever.

In the cases commonly seen both in epidemics and occurring sporadically, the blood stream phase is transient and succeeded rapidly by symptoms indicating involvement of the meninges. The incubation period is 2 to 10 days. There is a sudden onset with malaise, followed rapidly by stiff neck, nausea and vomiting. The temperature is irregularly elevated. The patient suffers from severe headaches and muscle pains and is usually delirious or stuporous, sometimes comatose. The musculature becomes rigid with contracture of the hamstring muscles (Kernig sign).

The course of the disease has been radically changed by the use of chemotherapeutic agents. Before the era of sulfa drugs, complications were frequent, many cases had a protracted course and were left with distressing sequelae. The case fatality rate ranged from 50 to 70 per cent in some outbreaks. Under modern conditions of treatment (Dingle and Finland, 1942) there has been a dramatic change. The case fatality rate has been reduced to less than 5 per cent. The deaths which occur are in those in whom the disease pursues a fulminating course; there is a fatal issue before effective therapy can be instituted. When conditions permit early institution of treatment with sulfonamide drugs, there is improvement in general condition and the temperature shows rapid return to normal, usually within 36 hours. The sensorium is usually clear within 48 hours, but headache and nuchal rigidity may persist for as long as a week.

**Bacteriologic Diagnosis.** Meningococci can be demonstrated in almost every case of cerebrospinal fever from one or more of three sources, namely, the nasopharynx, the blood, the cerebrospinal fluid. In fulminating cases, the Gram-negative intracellular or extracellular, biscuit-shaped diplococci may be seen directly in stained smears of capillary blood or of blood from a particular purpuric lesion. When meningeal symptoms are present a lumbar puncture is done and typical organisms may be demonstrated from direct smears made from the spinal fluid and stained with Gram. As the meningococcus is a very fastidious organism in its growth requirements, and extremely sensitive to cold and drying, recovery of these organisms by culture from the nasopharynx, the blood or the spinal fluid, requires specialized technics with appropriate media. For final identification, pure culture study and serological typing is necessary. According to Branham (1950) the following characteristics distinguish the meningococcus from other closely related *Neisseria*: "A Gram-negative coccus, usually occurs in pairs with flattened adjacent sides, which ferments dextrose, and maltose with the production of acid, forms characteristic colonies, does not produce pigment, usually grows only at body temperature.

and is as a rule at some time agglutinable by polyvalent antimeningococcus serum."

The meningococcus is a strict aerobe. Growth, especially from small inocula, however, is markedly enhanced by the addition of 5 to 10 per cent carbon dioxide to the atmosphere—a fact of importance in diagnosis and planning of studies. It is unusual to obtain proliferation at temperatures below 30° C or over 40° C, and the optimum is between 35° and 37° C.

These organisms are very susceptible to bactericidal agents. Drying, cold and the common germicides readily kill them even in low dilution. Over 98 per cent of case strains are inhibited in vitro by 0.5 mg. per cent or less of sulfadiazine. Penicillin is inhibitory in a concentration of from 0.1 to 0.5 units per ml. Tolerance, however, is rapidly developed in vitro to these therapeutic agents.

**Types of Meningococci.** When the meningococcus was identified by Weichselbaum in 1887, it was thought to be a homogeneous species. In 1909, however, Dopter isolated a strain which differed serologically from the original and called it parameningococcus. During World War I, this led the French investigators to classify meningococci into two main groups, Group A and Group B, recognized by British investigators as Group I and Group II. By the more refined technic of agglutinin absorption, Gordon and Murray recognized four types. Other investigators recognized the validity of this subclassification but there was some disagreement upon terminology and the antigenic range to be included in a single type. In the United States, it is believed to be impractical to distinguish between Type I and Type III which are classified jointly as Group I. Type II strains are not homogeneous serologically and are, therefore, more appropriately designated as Group II. A number of strains formerly classified as Type II, or Group II, have recently been separately designated and are now referred to as Group IIa. Type IV has not been isolated in the United States from cases and is so uncommon that its classification seems unwarranted at the present time. Some strains of meningococci isolated from the nasopharynx do not seem to fall into any of the known groups. They can be agglutinated by polyvalent horse sera but not by the specific rabbit or chicken sera employed in type indentifications. However, they are unimportant in the causation of the disease.

**Carriers.** In 1901, von Albrecht and Ghon called attention to the fact that not only patients but many apparently normal individuals, who, in so far as was known, had not had any contact with cases of meningitis, harbored meningococci in their nasopharynx. The existence of "carriers" afforded an explanation for much that had been obscure as to the spread of this disease. This observation was confirmed and many studies were conducted to determine the frequency and importance of these "carrier" infections during the epidemic and interepidemic periods. Since World War I, of 1914-1918, it has been realized to an increasing degree that cerebro-meningitis is in a sense a complication occurring occasionally among those who harbor the meningococcus in their nasopharynx. An excellent summary of the early studies is contained in the chapter on the "nasopharynx as the Habitat of the Meningococcus" in the monograph by Netter and Debré (1911). The isolation and identification of the meningococcus from the nasopharyngeal secretions is subject to many sources of technical error; but when these are minimized this micro-organism is constantly found in the nasopharyngeal secretions of the patient during the first



days of the malady. The carrier rate among those in the vicinity of patients has been found to vary; some observers reporting 5 per cent of carriers among the contacts, others as many as 50 or 60 per cent. The differences were thought to be due to the technical methods, the stage of the outbreak when the contacts were examined, and to environmental conditions. From information then available, Netter and Debré concluded that the intensity of the outbreak and the carrier rate corresponded. This point of view was confirmed by the studies of Glover (1920) on the control of cerebrospinal fever among troops in training in England in the course of World War I. Glover suggested that a "non-contact carrier rate" of 20 per cent or more was a danger signal and preceded the occurrence of cases of cerebrospinal fever in a military organization. However, Dudley and Brennan (1934), Rake (1934) and others, have found high carrier rates in populations where cases of meningitis were not occurring. Reviews by Maxcy (1937), Dingle and Finland (1942), and Aycock and Mueller (1950) questioned a fixed quantitative relationship between a crude carrier rate and a case rate. Apparently the ratio of nasopharyngeal infections to the occurrence of cases varies with many factors and conditions and is determined in part at least by the potential pathogenicity of the prevailing strains of meningococci.

According to Branham and Carlin (1942) more than 90 per cent of the cases of meningococcic meningitis during epidemics are due to Group I, whereas Group II is more often responsible for sporadic cases. By far the greater number of carrier strains recovered during nonepidemic times are Group II. Chronic carriers are especially apt to harbor Group II. During World War II, typing of strains isolated from cases throughout the Army indicated that 91.6 per cent were Group I. In an intensive study made at one Army camp, Phair and Schoenbach (1944) found that all of the cases of meningitis were associated with Group I meningococci, but in a group of 99 normal men, 53.5 per cent harbored meningococci Group I in their nasopharynx, 38.4 Type IIa and 50.4 Group II. This same group was kept under observation for 10 weeks and during this time were cultured three times weekly. The average composite prevalence rate was 40 per cent but 92.9 per cent were infected some time during the study period. Of the 92 men with positive cultures, 44 had infections classified as persistent under reasonable definition, and an approximately equal number had only transient infections. Cultures from some men were negative throughout the study period; spontaneous recovery from infection occurred in many; in others, infections of one type were followed, interrupted or accompanied by infection with another type. The extensive observations upon military personnel by Aycock and Mueller (1950) at Fort Devens and Camp Edwards, Massachusetts, led to the conclusion that the base upon which meningitis was occurring was the Type I meningococcus carrier rate. These studies confirmed the concept that the spread of meningococci is primarily at the subclinical level and that there is a carrier epidemic for the most part devoid of characteristic clinical manifestations preceding and accompanying the much smaller case epidemic. Moreover, it has been pointed out by Phair and Schoenbach (1944) that the frequency of cases occurring in successive time periods is related to the incidence of new nasopharyngeal infections with the prevailing pathogenic type of meningococci rather than the crude carrier prevalence rate at any given time.

Immunity. Distinction should be made between immunity to clinical attack, i.e., to invasion of the blood stream and or localization in the meninges, and

immunity to infection, i.e., to the growth of the organism in the nasopharynx. Evidently there is a high degree of natural immunity to clinical attack since only a small proportion, perhaps one in 1,000, of those who harbor the organism in the nasopharynx develop meningococcemia or meningitis. The degree of acquired immunity resulting from clinical attack is unknown but presumably durable. Second attacks are extremely rare. Since the morbidity rate, even during an epidemic, is so low (the annual rate rarely exceeds four per 1,000 individuals) the probability of observing a second attack in the same individual is extremely small. The problem is further complicated by the existence of immunologically variable meningococcic types. The formation of antibodies as a result of disease can be demonstrated by agglutination, mouse protection, quantitative precipitin reaction, complement fixation and bactericidal technics.

That some immunity is acquired is suggested by (a) the decrease in the attack rate with advancing age in civil populations, and (b) the greater susceptibility of recruits in military populations. With regard to civil populations, it has long been known that the attack rates from this disease were highest in infants and young children. Table 1-9 illustrates a typical civilian epidemic experience. The attack

Table 1-9. Age distribution meningococcic meningitis, Santiago, Chile, 1942

Age	Population	Cases		Deaths	
		Number	Attack Rate Per 100,000 Population	Number	Case Fatality (Per Cent)
Under 1 year	38,060	309	812	102	33.0
1-4	127,486	770	604	190	24.7
5-9	122,814	612	498	77	12.6
10-14	112,902	541	479	31	5.7
15-19	146,019	384	263	32	8.3
20-24	147,671	245	166	17	6.9
25-34	234,581	355	151	36	10.1
35-44	159,635	215	135	32	14.9
45-54	106,333	93	87	14	15.1
55-64	56,800	34	60	10	29.4
65 +	38,306	22	57	12	54.5
Unknown		6			

Adapted from Horowitz and Perroni, Arch. Int. Med., 74:365, Table 2, 1944.

rate was six to eight times as high among infants as it was among old people. On the assumption that all ages are equally exposed in the family, this age distribution is interpreted as indicating a gradual acquisition of immunity with advancing age. With regard to military populations, it has long been known that the attack rate among recruits was much higher than that among seasoned men. For example, Cook (1936) found that the attack rate in men with less than three months service was 10 to 46 times as great as that of men with more than one year of service. During 1942 and 1943 in the U. S. Army, Sartwell and Smith (1944) observed that of a total of 1,337 cases, 57 per cent occurred within three months after induction. Only rarely did men who had been in the Army more than a year develop meningitis.



Among military personnel, therefore, environmental age appears to be analogous with chronological age in civil populations with respect to the incidence of cerebrospinal fever. Since the clinical attack rate is too low to account for this acquired immunity, it appears probable that it is the result of experience with the meningococcus as a subclinical infection of the nasopharynx. It should be noted that an individual can harbor a specific antigenic strain of meningococcus in the nasopharynx for a period of time, then become negative on culture, and later harbor again either the same or a different antigenic strain (Phair and Schoenbach, 1944). Rake (1934) making repeated examinations on individuals working on one floor of a unit building of Rockefeller Institute in New York City, found four chronic carriers who harbored the organism from 21 to 26 months and were still positive when last observed. Evidently the resistance acquired to growth of the organism on the mucous membrane of the nasopharynx is of low order. Such experiences are, however, apparently sufficient in some individuals to confer immunity against clinical attack.

**Mode of Transmission.** The mode of transmission is essentially that described for other infections of the respiratory tract. It is to be noted, however, that the meningococcus dies very quickly outside the body when exposed to sunlight or drying. There are no extrahuman reservoirs of the disease. Propagation is maintained by person-to-person transfer. The contact must be of an intimate sort which permits nasopharyngeal secretions of one individual to reach the nasopharynx of another rather directly. This explains the association of the disease with crowded living conditions.

**Occurrence.** For the most part the disease has an endemic prevalence. Rarely is there more than one case in each household that is invaded. It is never long absent from any large population group. Sporadic cases occur throughout the year, the disease being most prevalent during the winter and spring months. Small outbreaks occur from time to time among troops in military installations, among inmates of refugee camps, prisons, orphanages and other institutions.

There are periods during which the disease is widely prevalent over large geographic areas. In these major epidemics, the spread may involve a single country or several adjacent countries, progressing gradually from one area to another, over a period of years. From a study of medical literature, Hirsh traced the occurrence of epidemic meningitis from about 1805 to 1886. He recognized four periods of unusual world prevalence. The movements of epidemics have been reviewed by Low (1916), Hedrich (1931), and Gover and Jackson (1946) from analyses of statistical reports of cases and deaths. Since 1916, there have been four distinct epidemic waves in the United States. The first began during World War I, reaching its maximum in 1917, and subsided slowly through 1924. The second period was of 10 years duration, from 1925 to 1934, with its peak in 1929. The third cycle extended from 1935 to 1940, with 1936 as the peak. In the last epidemic, cerebrospinal meningitis became increasingly prevalent in the United States just after the beginning of World War II, and the number of reported cases for 1943 and 1944 was the largest ever reported for the entire country. The peak was reached in 1944 and the incidence of the disease has progressively declined since that time. Although these epidemic waves extend over wide areas, the attack rates in the different communities vary widely. In military experience (Sartwell and Smith, 1944), although there is a high

degree of correlation between the incidence of meningitis and the crowding together of recruits in their sleeping, living and travelling quarters, this is not the whole explanation; other factors play a role. For example, at times it has appeared that some correlation existed between the occurrence of cerebrospinal meningitis and high attack rates from respiratory diseases, such as influenza and measles, accompanied by coughing and increased nasal secretions leading to more abundant dissemination of the micrococci of the upper respiratory tract. The effect of such factors as fatigue and chilling in lowering resistance to the disease is still a matter of speculation.

**Prevention.** Before the modern era, epidemic cerebrospinal meningitis was a highly fatal and much dreaded disease. With the introduction of sulfonamide therapy in 1938, the whole outlook on the prevention of deaths and cases was changed. In the U. S. Army during World War II the case fatality rate was below 5 per cent. This low rate has not been achieved by any large civilian community because of delays in providing medical care, laboratory diagnosis and prompt institution of sulfonamide therapy. To the extent that this is overcome by public health measures, complications and deaths from this disease can be reduced to a minimum.

Reduction in the clinical attack rate has become a practical possibility under favorable circumstances. New cases arise from contact with carriers and only rarely from contact with another case. While isolation of patients is a desirable precaution, it can play only an insignificant role in the prevention or spread of the disease. Indeed, with the introduction of sulfonamide therapy, the meningococcus disappears very rapidly from the nasopharynx of a case and the convalescent carrier presents no problem. To reduce the frequency of cases it is necessary, therefore, to decrease the frequency with which the meningococcus is passed from one individual to another, i.e., to reduce the carrier rate.

In the past, efforts to achieve this have been practical only in the limited population groups of institutions, camps, and military establishments. Principal dependence was placed upon reducing the amount of crowding in living and sleeping quarters and recreational facilities so far as practicable. Sometimes carrier surveys were undertaken, and attempts were made to discover and isolate all of the individuals in a group who were harboring meningococci in the nasopharynx. This procedure has proved unsatisfactory for many reasons.

Discovery of the extreme sensitivity of meningococci to sulfadiazine provided an effective means of reducing the carrier rate. It has been demonstrated by Kuhns and others (1943) and Schoenbach and Phair (1944) that by the prophylactic administration of small doses (totalling two to six grams) of sulfadiazine to an individual in an affected group, over a period of several days, the carrier rate can be reduced practically to zero. Cheever (1945) reported that among 600,000 men to whom one-half to one gram of sulfadiazine was administered daily for a period of seven weeks, only five cases of meningitis were noted, three of which occurred within 24 hours of chemoprophylaxis. During the same period, 146 cases were observed among a smaller group of untreated individuals.

In civil practice, this procedure is useful in the protection of familial contacts or small groups of people who have been exposed to a case. The administration of a prophylactic dose or doses of sulfadiazine insures disappearance of meningococci from the throat and decreases the risk of a secondary case.



While the prophylactic administration of sulfadiazine is an effective procedure under appropriate circumstances, due caution should be observed in its use. It should be given under careful medical supervision. A small proportion of individuals, perhaps one in 200, are hypersensitive to sulfonamide drugs and may have reaction of varying intensity. Administration of small doses of sulfonamides to a large population group over a long time period may result in favoring the survival of a drug-resistant strain. It is better, therefore, to give the drug over a short period of time, i.e., two or three days, and repeat if necessary a week or two later. Chemoprophylaxis once terminated does not insure freedom from subsequent infection. Meningococci surviving in the nasopharynx of some individuals or introduced by new arrivals may again spread and the carrier rate reach a level as high or higher than that at the time the prophylaxis was begun. Nevertheless, the procedure has its sphere of usefulness in tiding over a period of emergency and has had sufficient trial to show that it is practical.

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## TUBERCULOSIS

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Over the centuries, tuberculosis has been the foremost infectious disease as a cause of chronic disability and death in most parts of the world. Even today, when it is gradually coming under control in some countries, this is still true. The social and economic burdens which it creates are particularly devastating because its impact is heavily felt during the productive years of life, before the age at which cancer and heart disease make their greatest inroads.

Tuberculosis takes its greatest toll in regions with a low standard of living and among the underprivileged classes of the population. Although many other factors are involved, it is to some degree a barometer of social welfare; the downward trend in many countries has followed improvements in housing, nutrition, working conditions and the general standard of living of the masses.

One of the principal landmarks in the nineteenth century development of our scientific knowledge of tuberculosis was the work of Villemin, a French investigator, who in 1865 showed that the disease could be experimentally transmitted from animal to animal. Not only did this work indicate the transmissibility of tuberculosis, but it also demonstrated the unity of the disease in different hosts and of different clinical forms in the same host species. The concept of contagion, which in vague form can be traced far back in history, had gradually gained adherents despite the fact that in a chronic disease it is less easy to perceive than in epidemics of acute diseases. Two years after Villemin's work was published, William Budd, in England, assembled and described clearly many of the epidemiologic features of tuberculosis. He pronounced it to be a "true zymotic disease, of specific nature, in the same sense as typhoid fever, scarlet fever, typhus, syphilis, etc. . . . perpetuated solely by the law of continuous succession" and predicted that by disinfection of discharges containing specific morbid matter and by sanitary measures "we may, eventually . . . rid ourselves entirely of this fatal scourge." Budd had held these views for 10 years before he ventured to publish them. They are an illustration of the capacity of epidemiologic observations to lead to hypotheses later proved correct in the laboratory.

Koch's discovery of the tubercle bacillus (Koch, 1882) and his clear demonstration of its etiologic role was the most important single event in the whole scientific history of tuberculosis. Theobald Smith in 1898 differentiated the bovine from the human variety.

**Etiology.** The etiologic agent, *Mycobacterium tuberculosis*, is a nonsporebearing, acid-fast, rod-shaped micro-organism which can be cultivated on a considerable variety of artificial media, although growth is quite slow. It is pathogenic for most laboratory animals. There are several types, of which only the human and bovine types cause disease in man. The avian type is of agricultural importance because it produces disease in fowls and swine. The leprosy bacillus is a member of the same genus. A number of other species of acid-fast mycobacteria, most of which are saprophytic, have been identified. The differentiation of specific types of tubercle bacilli is largely based upon their relative capacity to induce disease in different species of laboratory animals.



Tubercle bacilli are destroyed by exposure to direct sunlight, by heat and by such disinfectants as phenol or tricresol solution. They are more resistant to chemical agents, especially acids and alkalis, and to antibacterial agents such as penicillin than are most pathogenic micro-organisms. They can remain viable for long periods in dried sputum. The concentration of chemicals and time of exposure to physical or chemical agents necessary for destruction of the bacteria depend on the nature of the secretions in which they are contained.

**Sources and Routes of Infection.** The principal source of infection is bacilli from the lungs and bronchi of persons with active pulmonary tuberculosis, contained in respiratory secretions that are coughed up and expectorated, or expelled in sneezing, talking or other respiratory effort. The organisms thus liberated into the environment may be directly inhaled in the form of droplets, or they may be reduced to droplet nuclei which remain suspended until inhaled (see Chapter 2); they may also become adherent to dust particles which are inhaled when stirred up. Wells, Lurie, and others have been able to infect rabbits by exposing them in chambers to aerosols of tubercle bacilli in suspension. Very small particles of the order of one micron diameter have the best chance of retention in the pulmonary alveoli, where they are most likely to initiate infection. Other possible mechanisms of infection are the contamination of the hands with bacilli-laden respiratory secretions and indirect transfer in this way to the mouth of the recipient, and contamination of food or eating utensils. The relative importance of these routes is not known, but such evidence as we have suggests that the inhalation of droplets or droplet nuclei deep into the respiratory passages is the chief mechanism. Drinking unpasteurized milk from tuberculous cows may initiate infection of the alimentary tract. Persons with extrapulmonary tuberculosis who are excreting tubercle bacilli, as in the urine or abscesses, but who do not have pulmonary lesions do not appear to be of any consequence as sources of infection. Infection may exceptionally be conveyed from tuberculous cows to stable workers (and the reverse is also possible).

The principal portal of entry of the tubercle bacillus is the respiratory tract. Primary lesions are most common in the peripheral portion of the lungs, indicating that the site of implantation is generally alveolar and that small inhaled droplet nuclei are likely vehicles for the organisms. The alimentary tract is a less important portal of entry; its relative importance will depend partly upon opportunities for ingestion of contaminated food. Primary lesions in the intestinal tract are rarely seen in the United States, but tuberculous mesenteric lymphadenitis is occasionally found. Tonsillar infection, with secondary cervical adenitis, may occur and very infrequently primary lesions in the skin or mucous membranes are observed.

**Pathogenesis.** The course of the disease is better understood in experimental animals than in man, and observation of its development in the guinea pig inoculated subcutaneously with virulent tubercle bacilli is instructive. After a latent period, an ulcer develops at the site of inoculation and tuberculin sensitivity appears, the regional lymph nodes become enlarged and caseous at the same time; later, disseminated tubercles appear and the animal dies. If a tuberculous guinea pig, infected several weeks previously, is again injected with tubercle bacilli, the local reaction is of a different character; it appears promptly, is severe and necrotic but circumscribed, and then heals (Koch phenomenon). The earlier infection, itself ultimately fatal, has altered the animal's response to subsequent reinfection.

In man, the sharp distinction once drawn between first infection and reinfection is no longer considered valid. Initial infection occurring in childhood is usually accompanied by gross enlargement of the regional lymph nodes (hilar nodes in the case of pulmonary infection) which may be roentgenographically visualized even when the primary focus is not visible, but this is not true of adults. Without knowledge of the individual's previous reaction to tuberculin, the initial infection cannot usually be distinguished from subsequent infection in adults. In the course of primary infection, bacilli are often borne in the blood or lymph stream to other organs in which tubercles develop. This post-primary dissemination occasionally gives rise to meningeal, miliary, renal or skeletal tuberculosis. Primary tuberculosis is frequently, however, a benign disease which heals spontaneously. Even in cases where roentgenograms reveal extensive pulmonary involvement, symptoms and signs are likely to be trivial or absent, especially in children. Occasionally, however, primary tuberculosis progresses to destructive pulmonary tuberculosis.

The pathogenesis of progressive pulmonary tuberculosis is poorly understood, especially in older persons. To what extent it results from reactivation of old primary lesions or foci resulting from post-primary dissemination (endogenous sources) and to what extent it is initiated by exogenous initial infection or superinfection has long been debated. As childhood infection becomes less frequent an increasing percentage of cases is probably attributable to recent infections. The initial appearance of tuberculous disease in a person past the age of 40, formerly considered unusual, is now observed not infrequently in the United States.

Pulmonary tuberculosis is a disease of highly variable character, ranging in severity from trivial infiltrates which never progress and are discovered only by accident, to virtual destruction of the lungs, and in speed of progression from extremely indolent lesions changing but little over many years to rapid development of pneumonic lesions. Progression may occur by direct spread or by way of the bronchi, blood or lymph stream.

Pleurisy with effusion is a common complication which may precede the appearance of roentgenographically visible parenchymal disease. In young adults at least, unexplained pleural effusions are likely to be of tuberculous etiology and are frequently followed within a year by pulmonary disease. Endobronchial tuberculous ulceration, which may lead to bronchial stenosis, is another common complication. In advanced disease, tuberculous laryngitis or enteritis may develop.

**Susceptibility and Resistance.** Once infection has taken place, the fate of the individual depends on a number of factors which are still poorly understood, and none of which can be quantitatively measured. Rich (1951) states that the extent and destructiveness of a tuberculous lesion depend upon the number and virulence of the bacilli that initiate the infection, the native and acquired resistance of the host, and the hypersensitivity of the host.

Lurie (1941) and Lurie and others (1955) showed by breeding experiments that in rabbits genetic constitution is a factor in native resistance. The resistant races are able more effectively to inhibit the growth of tubercle bacilli from the very beginning of infection. Kallman and Reisner (1943) demonstrated that when one of a pair of homozygous twins was tuberculous the co-twin was also tuberculous in most instances, while in the case of dizygotic twins or ordinary siblings the concordance was much lower. Puffer (1944) in family studies obtained suggestive



evidence of higher incidence among blood relatives of the tuberculous index case than among other household contacts. Thus, definite indications exist of hereditary factors in susceptibility.

Racial differences in susceptibility undoubtedly also exist. There is much evidence that Negroes are in general less resistant than white persons, although their higher mortality can partly be explained by environmental differences. Age at time of infection is an important factor; resistance is lower in infancy than at any other age, but the period from early childhood to the beginning of adolescence is one of relatively high resistance. Sex differences, though unimportant in childhood, are suggested by the more rapid rise of mortality after puberty in females and the later rise in males to a higher peak. The effect of pregnancy, apart from the burdens of caring for a family, is disputed.

There is good evidence that both silicosis and diabetes predispose to the development of active tuberculosis in the infected person. Influenza and measles probably have a similar, though temporary, effect.

It is very generally believed that many nonspecific factors such as nutritional deficiencies, fatigue, exposure to various kinds of environmental stress and perhaps emotional stresses as well have an adverse influence on resistance. We have, however, practically no scientific evidence bearing on their influence in man.

Thus, while exposure to the tubercle bacillus is one necessary factor for the development of tuberculosis, there are many poorly understood accessory factors which, taken together, determine whether the disease will develop in the exposed person and which might be thought of as etiologic in one sense. Osler's (1892) application of the biblical parable of the seed (the tubercle bacillus), the sower, and the soil (the host) is still apt. We have learned much about the seed but little about the biological characteristics of the host which determine the outcome of exposure. Tuberculosis is by no means unique among infectious diseases in this regard.

One of the most controversial issues in tuberculosis epidemiology has been the relation of tuberculin sensitivity to resistance. The importance of this question in relation to vaccination is obvious, since the only easily obtained measure of successful vaccination is the development of a positive tuberculin reaction. It is clear that the person who has been tuberculin positive for some time as a result of natural infection has already withstood successfully his primary infection, whether by reason of native resistance, age at infection, dosage of infection or for other reasons. It is also clear that whatever immunity may have been conferred by the initial infection is not very solid because active tuberculosis can develop at a later date in such persons. Comparisons between the incidence of tuberculosis in tuberculin-positive and tuberculin-negative groups are difficult to interpret for several reasons. Persons already infected have generally been more intensively exposed to tuberculosis in the past than uninfected persons and may still be subject to greater exposure. They may also differ with respect to socio-economic level, crowding and home hygiene. Those whose resistance was low have already been eliminated from the infected portion of the community by death or development of active tuberculosis. Furthermore, we must consider whether exogenous or endogenous sources of disease are more important; if the latter, the previously infected person would be at a disadvantage.

Students of nursing, whose environmental conditions are more or less similar during the years of training, have furnished the best data on this point. The findings of 21 comparative studies of nurses tuberculin positive or tuberculin negative on entry in training were summarized by Daniels (1944). Tuberculosis morbidity and mortality were generally higher in those who were negative at the beginning of training. The hazard of developing clinical disease was greatest during the first year after conversion of the tuberculin reaction, the degree of excess hazard depending on whether such minor manifestations of disease as erythema nodosum, pleurisy with effusion and uncomplicated primary complex were counted under morbidity. On the other hand, in community surveys certain workers, as for example Pope and others (1939), showed that subsequent tuberculosis morbidity and mortality were higher among children who were already tuberculin positive but free from clinical disease when they came under observation than among those still tuberculin negative. This may be explained by the environmental differences discussed above and by the likelihood that some of these children had been infected only recently.

Long (1950), in summarizing the development of current concepts on resistance, states that, in either native or acquired resistance, prompt localization of invading bacilli at the portal of entry is a significant element.

**Diagnosis.** Symptoms of pulmonary tuberculosis are variable, often insidious, and likely to appear late in the disease. They include fatigue, weight loss, fever and night sweats, cough, expectoration, chest pain (often pleuritic), hoarseness and occasionally hemoptysis. Physical signs are those of consolidation, excavation or pleural effusion; fine inspiratory rales may be the earliest sign. Local manifestations of extrapulmonary tuberculosis depend on the organs involved.

Accurate diagnosis rests on the triad of tuberculin testing, roentgenographic findings and bacteriologic study. Since these are of importance in both clinical study and public health programs, they will be discussed in some detail.

The first diagnostic procedure, the tuberculin test, has always been important in pediatric practice. It is also of increasing value in ruling out tuberculosis in adults with roentgenographic evidence of disease from whom tubercle bacilli cannot be recovered, since a large percentage of adults in many areas are now uninfected. In epidemiologic investigations the tuberculin test affords the only means of determining the prevalence of infection in a population.

Old Tuberculin (OT) is a glycerinized extract of heat-killed tubercle bacilli and their metabolic products, obtained from filtrates of fluid cultures. Seibert (1934) has developed a more refined product termed Purified Protein Derivative (PPD) which contains less nonspecific substances and is of greater uniformity. This product is gradually replacing OT in survey work. International standards of OT and PPD have been established. In recent years a common unit of potency, the Tuberculin Unit (TU), has been introduced. By definition, one TU is 0.00002 mg. International Standard PPD or 0.00001 ml. ("0.01 mg.") International Standard OT. It has been shown, however, that the two tuberculins are qualitatively as well as quantitatively different and that their relative potency varies from one dosage level to another.

Many technics of testing have been devised. The principal ones in use today are the quantitative intracutaneous (Mantoux) test employing graded dilutions of OT or PPD, the Vollmer patch test and the von Pirquet or scarification method.



The Mantoux has the greatest accuracy but the Pirquet is easy to perform and requires less equipment. The patch test is widely favored because of its ease of application and advantages for young children. However, it is somewhat inaccurate both because of the uncertainty as to whether the subject has kept the patch on for the required period and the greater difficulty of interpreting reactions; it is also more expensive.

Reactions are interpreted after 48 to 72 hours (in the case of the patch test the patch is removed at 48 hours and the reaction is read at 96 hours). With the Mantoux or Pirquet tests the transverse diameter of the area of induration should always be measured and recorded. The Mantoux test is usually considered positive when the reading is 5 mm. or more.

With the intracutaneous technics, 1 TU of either of the two tuberculins has often been used as a first dose in order to avoid troublesome reactions, followed in the case of nonreactors by larger doses, up to 100 TU of OT or 250 TU of PPD. However, the work of Palmer, Furcolow and others has demonstrated that many reactions elicited only by large doses of tuberculin are probably nonspecific and that such reactions show wide geographic variations in frequency. Therefore, the utility of doses greater than 10 TU is very doubtful. In the United States, a number of recent surveys have been carried out with the Mantoux test employing 0.0001 mg. of PPD (5 TU) as the only dose. For epidemiologic purposes, standardization and simplification of technics and dosage is obviously desirable. No tuberculin should be used that has not been compared in potency to that of the corresponding international standard.

The tuberculin reaction has high sensitivity for the detection of clinical tuberculosis. Few proven cases fail to react to 5 or 10 TU of either tuberculin. Sensitivity is depressed in critical illness, in measles and perhaps in pregnancy. How often persons positive to small or moderate doses of tuberculin lose their reactivity and revert to negative is unknown; this has been observed in infants treated with isoniazid but is probably infrequent in the general population.

The specificity of clear-cut reactions to small doses as an indication of previous or recent infection with tubercle bacilli is also high, although of course the reaction does not signify active disease. It becomes positive about four to six weeks after initial infection has taken place and before the appearance of clinical manifestations of disease. Thus, conversion of the reaction from negative to positive in an individual signifies that infection has taken place during the period between the last negative and first positive reactions or just prior to the last negative result. The first 6 to 12 months after conversion is a period when individuals should be closely observed for the development of tuberculous disease. Fluctuation in the intensity of the reaction in an individual has not been shown to have clinical significance.

The chest roentgenogram, properly performed and interpreted by skilled persons, provides a sensitive test of the presence or absence of pulmonary disease compatible with tuberculosis, and by serial films the progression or retrogression of established disease. As a screening procedure applied to contacts, suspects and supposedly healthy groups it has revolutionized case finding. Examination of large numbers of persons at minimal cost has been greatly facilitated by the development of photofluorographic equipment, with which the fluoroscopic image of the thorax

is photographed on a small film. This is supplemented by conventional roentgenograms in all cases in which it reveals positive or suspicious findings.

There are, however, limitations in roentgenography as a diagnostic tool which need to be appreciated. First, the roentgenologic appearance of tuberculous disease is not pathognomonic, and many other diseases can produce changes which require further study by other methods to distinguish reliably from tuberculosis. These include bacterial, viral and fungus infections of the lungs, malignancies, sarcoidosis and pneumoconiosis, among others. Second, the film reader's findings are subjective in nature and are much less accurate than was formerly supposed. This was first demonstrated in a study by Birkelo and others (1947) and has been amply confirmed. The same series of chest survey films, when read independently by several expert roentgenologists, or even when read several times by the same roentgenologist, will often reveal marked disparities in the cases classified as "tuberculosis" or "suspected tuberculosis." Recognition of this has suggested the practice of multiple readings of survey films, which will reduce the number of cases that are overlooked but at the same time will increase the number of persons erroneously called cases or suspects and placed under observation. The third limitation in roentgenography is that a single chest film cannot distinguish between active and inactive tuberculous disease in many cases. Other methods, coupled with repeated roentgenologic examinations at appropriate intervals, must be employed for this purpose.

Identification of tubercle bacilli in sputum or other secretions gives a specific diagnosis and a knowledge of the activity of the disease, thus complementing the information provided by roentgenogram. The simplest but least sensitive method is direct microscopic examination of a Ziehl-Nielsen stained smear of sputum. Culture of sputum or, if this cannot be obtained, of gastric washings, tracheal washings or laryngeal swabs is much more sensitive and should always be done if microscopic examination is negative. Since it is useful in distinguishing tubercle bacilli from saprophytes, it should be carried out in all cases if possible. Several examinations are often required before tubercle bacilli are found; hence, reliance should never be placed on a single negative report. Inoculation of material into guinea pigs remains the most reliable bacteriologic procedure because of its high sensitivity, its simplicity and its ability to distinguish pathogenic from nonpathogenic organisms.

**Classification.** The National Tuberculosis Association (1950) recommends a classification of pulmonary tuberculosis by extent into minimal, moderately advanced and far advanced stages, and by clinical activity into active, arrested and inactive categories. A definition of each stage and clinical category is provided. It should be understood that the classification by stage is purely anatomical and does not connote duration; thus, minimal disease may be early disease or may equally be of many years duration.

Other forms are classified according to the organ system involved. Table 1-10 is presented to indicate the relative importance as causes of death of the principal extrapulmonary forms in the United States at the present time. It is seen that pulmonary tuberculosis accounts for over 90 per cent of the fatalities, with meningeal and disseminated (miliary) tuberculosis responsible for most of the remainder.



**Therapy.** There have been three major developments in the treatment of tuberculosis: the sanatorium, collapse therapy and specific antibacterial drugs. These should be considered both from the viewpoint of their therapeutic value for the individual patient and their significance in relation to the public health.

Sanatorium treatment, introduced at the close of the nineteenth century, has three objectives: the provision of a hospital for closely supervised medical care; the indoctrination of patients in those living habits which offer the best chance for recovery and freedom from relapse; and the segregation of open cases to protect their families and the community against infection. Over the long period when no specific antituberculosis measures were available the sanatorium was the focus of the tuberculosis control program. A regime of carefully supervised rest, nursing, good food and medical supervision is still of major importance. The earliest sanatoria were privately operated, but public institutions rapidly took over the task. By 1955 there were indications that sufficient sanatorium beds were at last available in the United States, although they were not evenly distributed and many communities still had waiting lists. However, the construction and operation of sanatoria is one of the most expensive aspects of tuberculosis control, and in many countries whose economic resources are unequal to the burden, hospital facilities will be available for only a small fraction of the active cases for years to come.

Table 1-10. Number of deaths and death rates for tuberculosis by specified form, United States, 1952

(Exclusive of deaths among armed forces overseas. Rate per 100,000 estimated midyear population excluding armed forces overseas)

	Number of Deaths	Per Cent of Total	Death Rate
Tuberculosis—total of all forms	24,880	100.0	16.0
Tuberculosis of the respiratory system	22,745	91.4	14.6
Tuberculosis—total of other forms	2,135	8.6	1.4
Tuberculosis of the meninges and central nervous system	767	3.1	0.5
Tuberculosis of the intestines, peritoneum and mesenteric glands	150	0.6	0.1
Tuberculosis of the vertebral column	139	0.6	0.1
Tuberculosis of the bones and joints (except vertebral column)	63	0.3	*
Tuberculosis of the lymphatic system	39	0.2	*
Tuberculosis of the genito-urinary system	228	0.9	0.1
Tuberculosis of other organs	71	0.3	*
Disseminated tuberculosis	678	2.7	0.4

\* Less than 0.05.

Practically all infectious cases profit from a period of residence in a sanatorium. It has never been possible, however, to hospitalize all cases present in the community at a given time. Patients with limited involvement, in comfortable homes where there are no children, and able to take the necessary hygienic precautions may be allowed to remain at home. The necessary period of institutional treatment may be shortened by specific drug treatment; this is under study at present.

Rehabilitation work in the sanatorium and after discharge is playing an increasing role in the management of tuberculosis. Its object is to retrain the patient so

that he can when fully recovered take up an occupation suited to his physical limitations and thus reduce the likelihood of reactivation of disease. The social worker is also an important member of the sanatorium staff whose responsibility is to help the patient and his family solve the many problems, economic and social, which arise during this chronic illness.

A vexing problem has been created by the unwillingness of many patients to remain in sanatoria until considered medically ready for discharge. Others refuse sanatorium treatment altogether and some of these, because of their living habits, are a distinct hazard to their associates and to the public generally. Legally enforced segregation of these recalcitrants has been tried but has had limited use because of the fear of its adverse effect on the willingness of others to accept treatment.

In an earlier day, when the influence of climate on recovery was stressed, tuberculosis hospitals were constructed in out-of-the-way places. In recent years, the tendency has been to build them close to the population served (Chadwick and Pope, 1946). Among other advantages, this makes available the services of a better consulting staff. There has also been a trend toward treatment in general hospitals. With drug therapy, it appears that physicians in the community will assume much larger responsibility for the management of tuberculosis than was the case in the past quarter century when it was largely relegated to specialists in institutions. This necessitates greater attention to the clinical aspects of the disease both in medical schools and in postgraduate medical education.

Various methods have been used to collapse the diseased lung. The first was artificial pneumothorax, once used very extensively but now only occasionally. It has been partially replaced by pneumoperitoneum. Phrenic nerve interruption, thoracoplasty and extrapleural plombage are surgical measures which are of benefit in a certain number of cases. Recently, with the improvement in surgical technics, there has been a marked increase in surgical extirpation of diseased lung tissue by pneumonectomy, lobectomy or segmental resection. All of these procedures, employed in properly selected cases, are of value in rendering patients sputum negative and aiding in the arrest of the disease. They are adjuncts to proper general medical care.

Antimicrobial drug therapy, in the decade since it was introduced, has become the most important element in the medical management of tuberculosis. Methods of treatment are changing as knowledge increases, but the present position will be briefly summarized. Drug treatment is indicated in almost all instances of active tuberculosis of any organ, except perhaps in benign primary tuberculosis in older children. Isoniazid and streptomycin are the most effective drugs, administered together or with para-aminosalicylic acid. Several other promising agents are under study. Drug therapy must be continued for at least one year and often longer. Each of these drugs can occasionally produce toxic effects necessitating a change in the regimen. The development of drug-resistant strains of tubercle bacilli in patients under treatment is not uncommon and may be detected by *in vitro* sensitivity tests, although the correlation between results of such tests and clinical response is not perfect. Drug treatment may, if delay in hospitalization is unavoidable, be commenced before admission to hospital. In persons known to have been recently infected as indicated by tuberculin conversion, especially children, prophylactic



chemotherapy has been proposed but is not yet widely recommended, pending the outcome of current controlled studies.

There is no doubt that antibacterial drugs have radically improved the previous hopeless prognosis in miliary and meningeal tuberculosis, nor that they have greatly lengthened survivorship in pulmonary and other forms. There has not been time for measurement of the ultimate prognosis in pulmonary tuberculosis treated with these drugs. Along with the clinical improvement, sputum conversion in pulmonary tuberculosis is usual, but relapse can take place and patients whose disease has become inactive cannot be regarded as cured in either a bacteriological or clinical sense. Early discovery of active tuberculosis and close supervision of recovered cases remain essential, as do other well-established elements in treatment (rest and adjunct surgical treatment).

**Frequency of Infection.** Tuberculin testing of population groups has been done for many years on a wide scale, yet differences in technics and in the selection of subjects and the dearth of long-term programs have restricted the comparative knowledge gleaned from them. Certain general statements may be made, however. The percentage of reactors rises steadily with age to adulthood but may show a slight decline after the age of 50 or 60. The age curves are similar for males and females in childhood but may be somewhat higher for males in adult life. In families where there is an open case of tuberculosis, the rise is much faster. In crowded environments and areas where the tuberculosis death rate is excessive the rise is more rapid than in rural communities. Evidence of an occupational hazard is afforded by the fact that students of nursing and medicine in some situations have shown a higher risk of infection than other groups.

There has unquestionably been a sharp drop in the prevalence of infection in the United States in recent years. Thus, while past surveys not infrequently revealed 30 per cent or more of young adults reacting, Canada and Babione (1950) found that fewer than 10 per cent of young adult males entering the Navy in 1948 were positive to 5 TU of PPD. A marked drop has been observed in the number of reactors among students entering colleges.

Information on the tuberculin status of older adults is much less abundant. A community-wide program was conducted by Comstock in 1950 in Muscogee County, Georgia, employing a single test of 5 TU PPD. His findings on residents of the urban area of the county are presented in Figure 1-11.

The BCG program conducted by the International Tuberculosis Campaign (1951), a partnership of UNICEF and three Scandinavian volunteer organizations with guidance from WHO, has provided valuable information on the prevalence of infection in many other countries. Children from ages 1 to 18 were tested, usually with 5 or 10 TU of PPD (in some countries the Moro test was used for children under 12). Countries of Eastern Europe, North Africa, the Middle East, Asia and Latin America participated. In most places as many as 50 per cent of children were infected by age 15, the number being higher in the cities than in rural areas.

**Prevalence and Incidence of Pulmonary Tuberculosis.** This may be measured either by the rate of discovery and reporting of new cases or by the results of mass roentgenographic surveys. Each method has serious defects for comparative purposes. The first is dependent upon the activity of case-finding programs and the

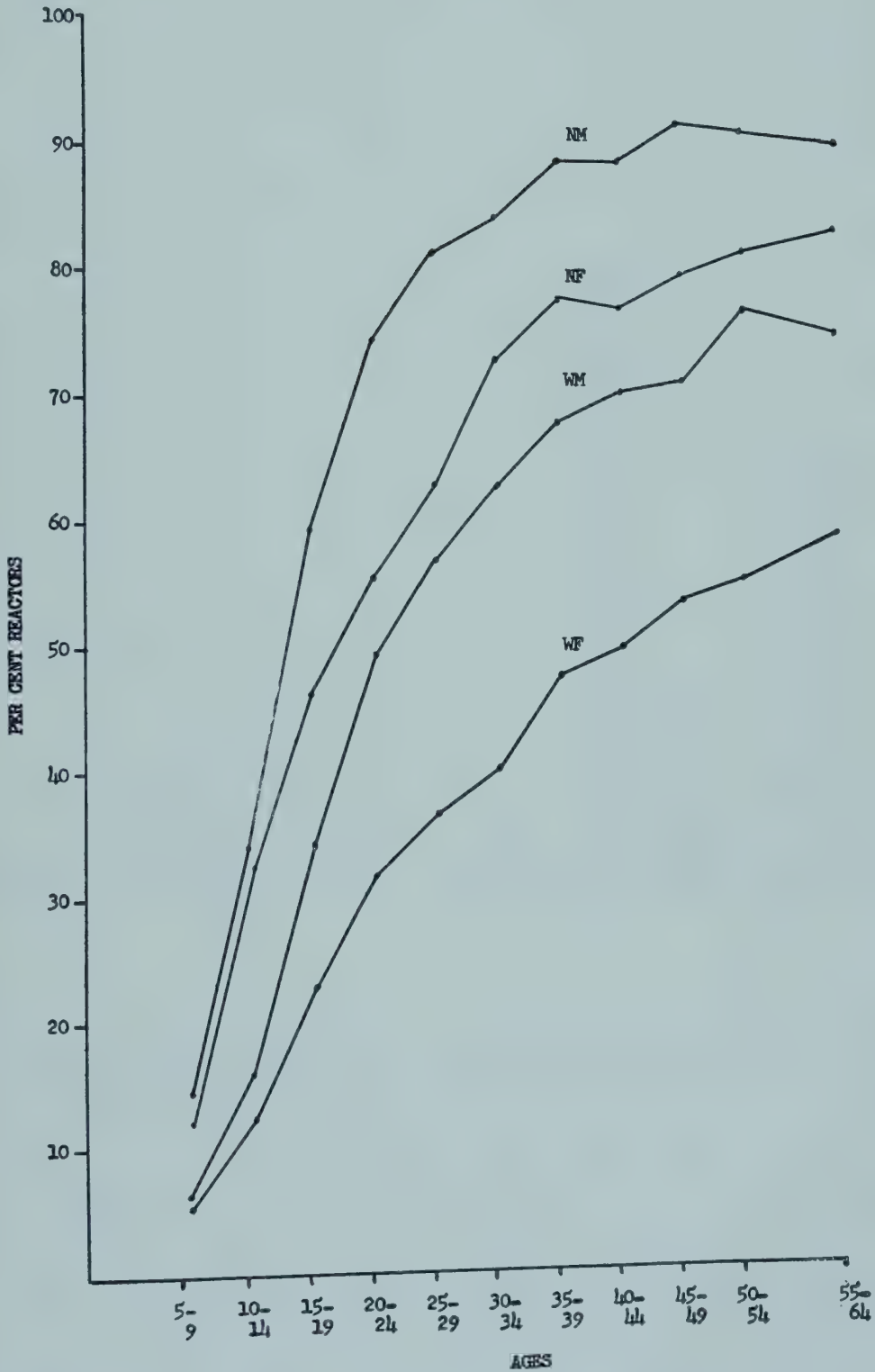


Fig. 1-11. Percentage of persons in Columbus, Georgia, who reacted to 0.0001 mg. PPD. in 1950, by age, race and sex. NM, Negro male. NF, Negro female. WM, white male. WF, white female.



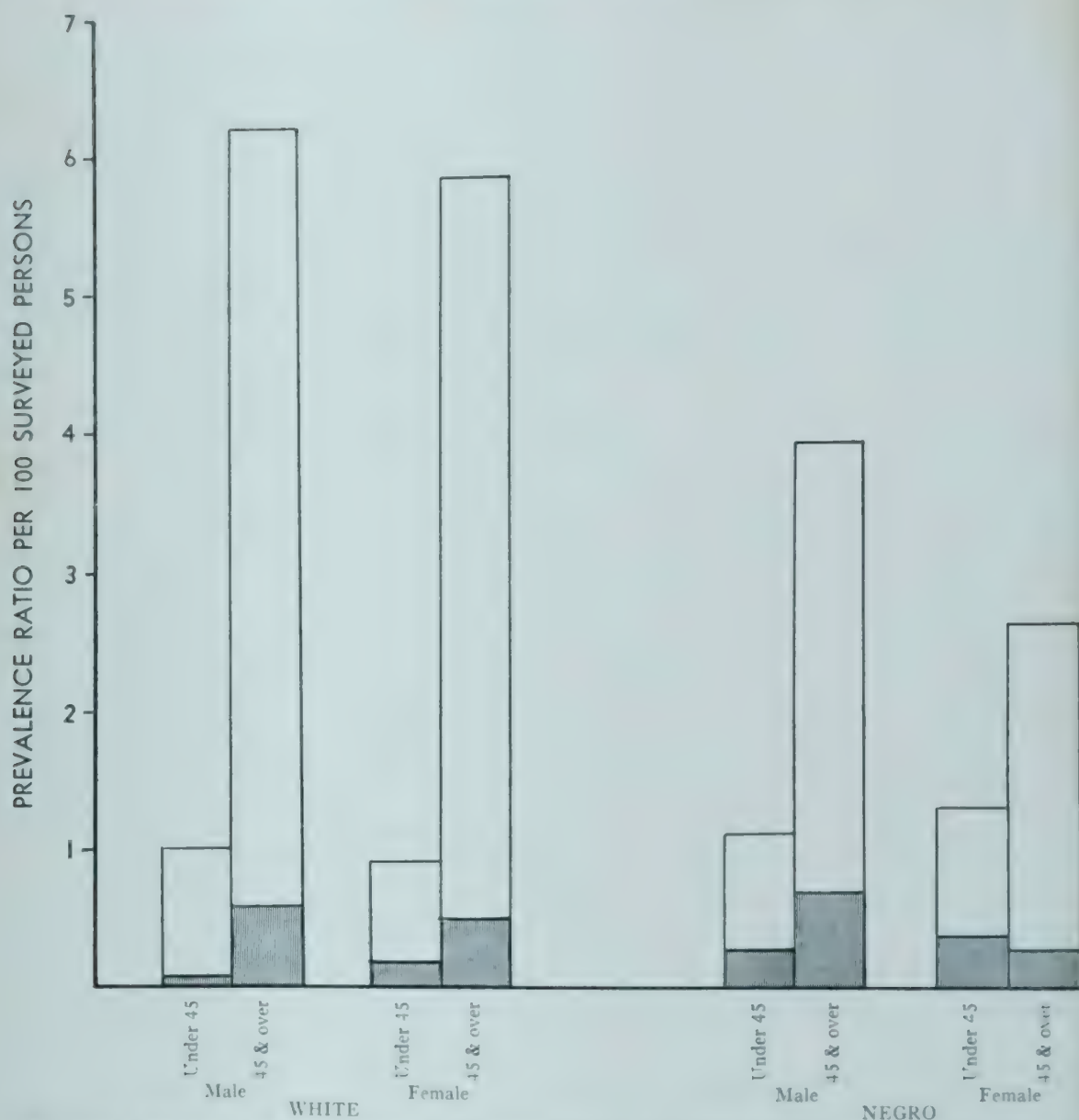


Fig. 1-12. Prevalence of tuberculosis per 100 persons examined in 1946 photofluorographic survey, Muscogee County, Georgia. Height of bar: persons "to be followed" on basis of 1946 films. Shaded portion: cases found bacteriologically positive in 6 years' observation.

practice with regard to reporting of cases, and results of the second depend on what population groups are selected for examination, as well as the diagnostic criteria employed. The incidence rate as measured by reported cases in most sections of the United States showed a slight to moderate rise during and immediately after World War II when mass surveys were introduced on a very wide scale but has since declined slowly but progressively. Bed occupancy has also declined a little in the past few years; this decline is probably due both to the falling incidence of disease and to improved therapy which has shortened the period of hospitalization.

While mass surveys are not suitable for comparison of prevalence in different places or for studying time trends, they do give a useful picture of the relative prevalence by age, sex and race. The community survey in Muscogee County,

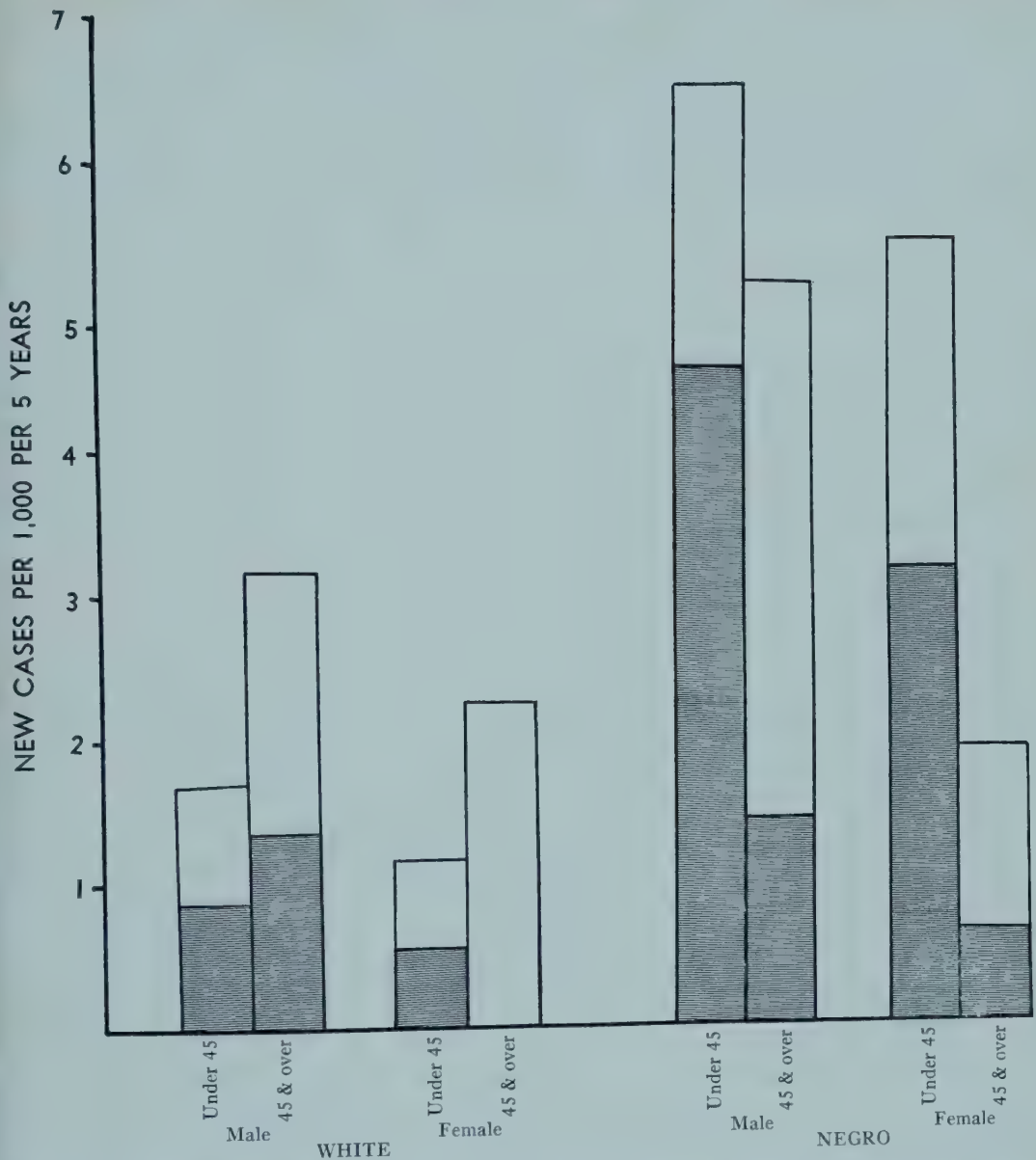


Fig. 1-13. Discovered incidence of new cases of tuberculosis among persons with negative photofluorograms in 1946, in subsequent 5 years, Muscogee County, Georgia. Rates per 1,000 population per 5 years. Height of bar: total confirmed and suspect cases. Shaded portion: bacteriologically positive cases.

Georgia (Comstock and Sartwell, 1955), revealed that total prevalence increased markedly with age but that a much larger proportion of cases in the younger persons were active. Comparison between white and Negro prevalence showed a somewhat higher total prevalence in whites, but again a larger proportion of discovered Negro cases was active (Fig. 1-12). The incidence of new cases in a 5-year period after the survey, among the population who were negative by roentgenogram at the time of survey, was higher in Negroes and especially in those under 45 (Fig. 1-13). The fact that Negroes have a higher incidence and yet a lower prevalence of tuberculosis than white persons is an apparent paradox; it is explained by the greater likelihood that the white person will survive his infection and subsequently be discovered as an inactive case.



**Mortality.** Until recently, the mortality rate provided the best single measure of the magnitude of the tuberculosis problem in a community and of time trends, for those countries where causes of death were determined with reasonable accuracy. There are still, however, many areas in the world where, because of lack of medical services and the consequent inaccurate certification of causes of death, the mortality rate cannot even be estimated. Furthermore, since the advent of

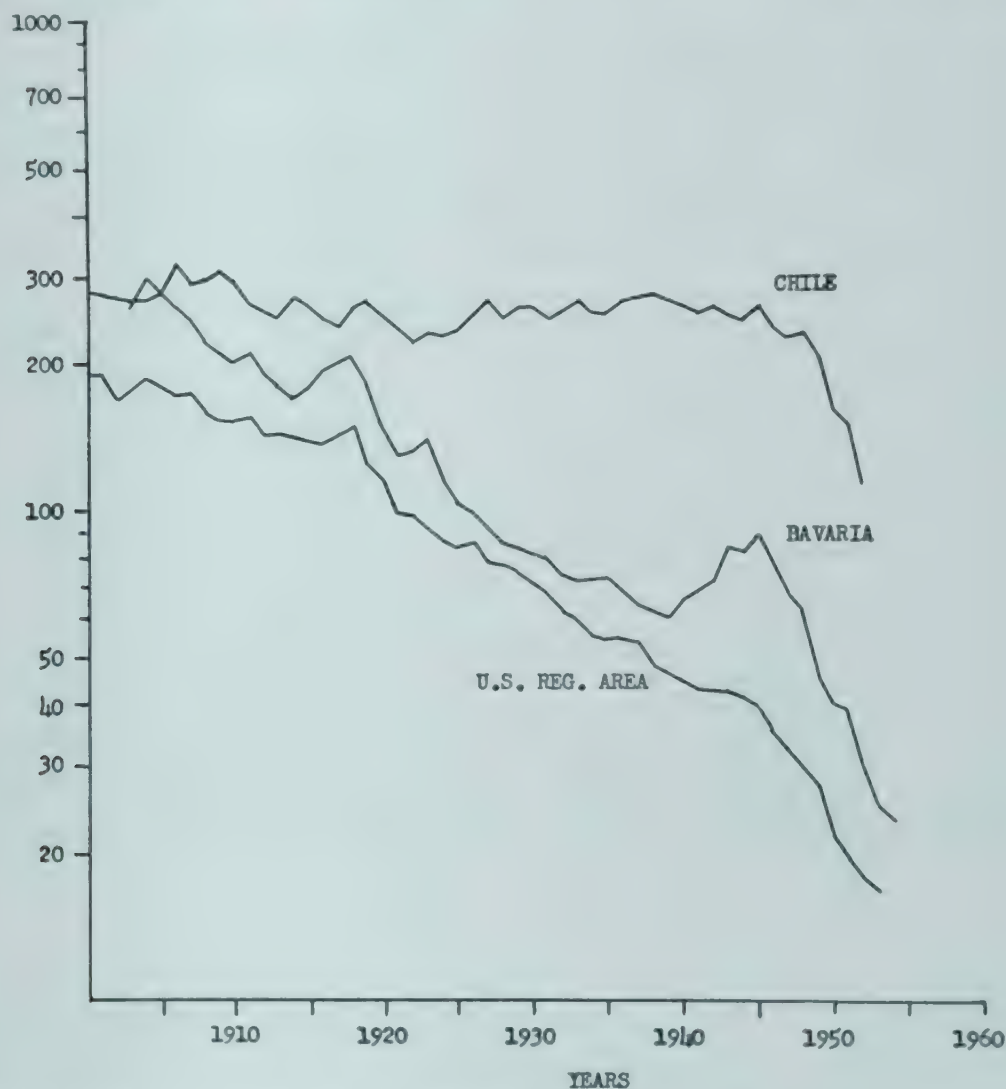


Fig. 1-14. Mortality rates for all forms of tuberculosis, per 100,000 population (logarithmic scale).

effective drug therapy mortality rates can no longer be looked upon as reflecting directly the trend of morbidity.

Although the records are fragmentary and unreliable, there are indications that tuberculosis mortality was on the increase in the early part of the nineteenth century in Europe and reached its highest levels during the period of industrial revolution. Since reliable rates have become available, however, the trend of mortality in the United States, Great Britain and most of the Commonwealth nations, and several European countries has been steadily downward for many years, being interrupted only by wars and economic depressions when these had serious effects

on civilian life. Over the past quarter century in the United States, this trend has been most rapid for infants and for the more acute forms of the disease (miliary and meningeal) often seen in infancy. From 1900 to 1916 the rate of decline was about 2 per cent per year; after a brief rise, coincident with World War I and the 1918 influenza pandemic, the decline was resumed at an accelerated rate, about 4 per cent per year. Beginning about 1948, the downward trend has been sharply accelerated, and there is little doubt that this was due chiefly to the introduction of specific drug therapy, although a change in the method of classifying causes of death was also made at that time.

Figure 1-14 shows the rates from 1900 in the United States contrasted with Bavaria and Chile, the rate scale being logarithmic. It will be noted that the trend in Bavaria has generally paralleled closely that in the United States but that there have been three major interruptions occasioned by World War I, the economically disastrous inflation of 1922-23, and World War II. Of these, the rise in World War II was the most serious, while in the United States, where the war had much less effect on civilian populations, there was little change in the trend. Rates for Chile are included to show one of the countries where mortality remained high over a long period but has recently dropped sharply. It has been suggested that the rapidly increasing industrialization of Chile was responsible for the sustained high rates.

Along with the downward trend, a shift in age distribution of mortality has occurred, especially among males. This is illustrated by data for England and Wales for three periods (Fig. 1-15). The decline in young adult life has been much greater than for older persons. This observation seems to indicate that an individual now encounters his greatest risk of death from tuberculosis at an advanced age in contrast to the experience some years ago. However, Frost (1939) pointed out that if viewed in the light of prior experience of the cohorts comprising each age group, a different conclusion might be reached. The cohorts now experiencing the highest mortality rates are those who in earlier life had still higher mortality. Analysis of mortality in Massachusetts on this cohort basis shows that each cohort observed through most of the life span of its members has experienced its highest mortality in infancy and its next highest in the third decade of life, the rates declining thereafter. This suggests that survival through a period when tuberculosis mortality was high implies a continued excess risk of dying from tuberculosis, owing perhaps to the delayed effects of earlier infection.

There has also been a marked change in the relative mortality of males and females, consequent on the faster downward trend of female rates. In 1900, males in the United States had the lower mortality rate, while in 1954 the male rate was more than twice as high as the female. We have no satisfactory explanation for this shift.

Some countries (e.g., Japan) did not share in the decline in mortality prior to 1945 but in most of these it is now going down rapidly. Others, mostly in underdeveloped parts of Asia, Africa and South America, whose mortality records are too inaccurate for the visualization of trends, still are known to have a continuing high toll of death.

In the United States, tuberculosis mortality is much higher in Negroes than in whites and is also high in the Spanish-American population of our southwestern states. Wolff (1940), in studies of mortality in different countries, found that



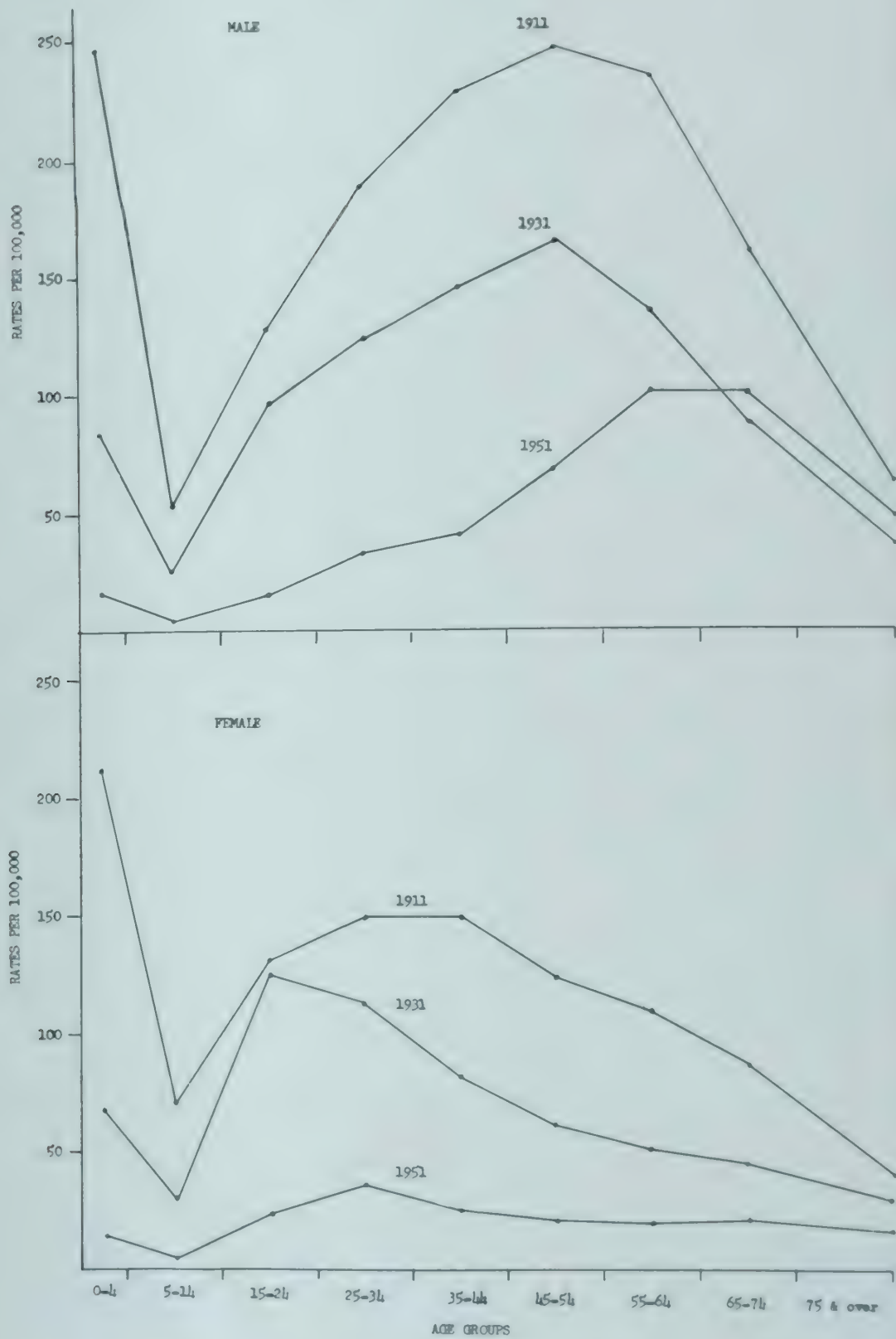


Fig. 1-15. Mortality from all forms of tuberculosis, England and Wales, by sex and age in 1911, 1931 and 1951. Annual rates per 100,000 population.

industrialized nations in general had lower mortality rates than predominantly agricultural ones, a difference which he attributed to the higher standard of living in the former. Within the United States, on the other hand, he found positive correlation between mortality rates of states and their index of industrialization.

Studying the effect of economic status on tuberculosis mortality by age and sex, Terris (1948) divided the population of Buffalo, New York, into economic quarters, using four indices. He found that the difference in mortality by economic level was small for females and young males, but there was a great difference for males over 30 years of age, mortality declining as economic status improved. Terris suggests that conditions of occupation, in addition to economic status per se, are responsible for this effect. It has been amply demonstrated that mortality varies with occupational class, being lowest in the professional groups and highest in unskilled workers.

**Familial Spread.** The enhanced risk of tuberculosis in families where one member is already suffering from the disease has been appreciated for many years. It required planned long-term observations, however, to document this and to demonstrate the degree of excess risk. Such studies were done by Downes (1935), Brailey (1940) and Puffer and others (1952). The life-table method of analysis of data suggested by Frost (1933) has been helpful in contrasting the experience of tuberculous households with control households or the general population. Prevalence of tuberculosis in household contacts of "index cases" at the time of their initial examination is considerably higher than in the general population. Periodic examination of such household contacts has revealed a continuing excess incidence of new cases over a period of years. Their frequency of infection as revealed by tuberculin testing is also much higher than in the rest of the community (McPhedran and Opie, 1935). As would be expected, contacts of positive or advanced cases sustain higher risks of infection, disease and death than contacts of sputum-negative cases. These risks also vary according to age, sex and race; the age at which exposure took place; and presumably the duration and intensity of exposure.

**Vaccination.** Almost from the discovery of the tubercle bacillus, efforts have been made to develop an immunizing agent, although, since the immunity provided by natural infection is indecisive, the hope for an effective vaccine was not very great. Many types of vaccine have been tried on experimental animals, and at least three—killed virulent bacilli, living attenuated strains and living vole bacilli—in man. Out of this work there has emerged one agent, BCG, which today is used over the world but about which dispute still centers.

BCG (bacillus Calmette-Guérin) vaccine is composed of living bovine type tubercle bacilli which have undergone attenuation until they are no longer capable of inducing progressive tuberculosis. In the course of prolonged subculturing on a medium containing ox bile, this strain was found to have lost most of its virulence (Calmette, 1928). It was originally employed in France as an oral vaccine administered to newborn infants. A considerable proportion of such infants became tuberculin positive but for a long while no adequate test of its efficacy in preventing tuberculosis was undertaken.

Heimbeck (1932) in 1927 undertook the subcutaneous vaccination of tuberculin-negative student nurses in Oslo and found a much lower incidence of tuber-



culosis among the vaccinated nurses than among those who declined immunization. Following this promising work its use became more widespread, especially in Scandinavia, and further evaluation was undertaken. In the United States, Rosenthal and others (1945) vaccinated children in tuberculous households; Park, and later Levine and Sackett (1946), carried out a similar project in New York; and Aronson and his associates (1952) vaccinated Indian children. In Canada, Ferguson and Simes (1949) also vaccinated Indian children. All of these studies included controls, i.e., unvaccinated children so selected as to be thought to have a similar tuberculosis risk, although in some of them the controls may be criticized as being selected by less than ideal methods. Each of the cited investigations, with the exception of that by Levine and Sackett, produced evidence that vaccinated children were protected to some degree, though not completely.

The study by Aronson is perhaps the most impressive because of the long observation period and the large number of subjects. There were 1,551 vaccinated children and 1,457 tuberculin-negative controls among 8 tribes living in 5 areas of the United States and Alaska. They were kept under periodic observation, with some lapses, for a period of 13 to 15 years, at the end of which time there had occurred 12 deaths from tuberculosis among the vaccinated and 65 among the controls; deaths from other causes were about equally distributed between the two groups. Similar results prevailed in the Canadian study, which was smaller but in which the selection of controls was perhaps more satisfactory.

In Denmark, the accidental infection of a number of school children by a tuberculous schoolteacher (Hyge, 1949) furnished an indication of the efficacy of vaccination, since a portion of the class had been recently vaccinated and others were still tuberculin negative. In Sweden (Dahlstrom and Difs, 1951), data on the incidence of tuberculosis in vaccinated soldiers contrasted with others who refused vaccination pointed in the same direction. Neither observation is wholly convincing but they support the conclusions drawn from all but one of the controlled studies, that a moderate degree of protection is conferred.

Most of the work cited was done under somewhat special circumstances: the subjects were children, the risk of tuberculosis was high, and the observation periods after vaccination were rather brief. Nevertheless, within the limits of the experiments, the evidence is rather impressive.

In programs of tuberculosis control, not designed to provide scientific evidence of the value of BCG, many millions of people in many parts of the world have been vaccinated, largely since World War II. This experience has at least provided evidence of the general harmlessness of BCG, for only two fatalities reasonably attributable to the vaccine have been reported. In these cases it seems fairly clear that the organisms which produced progressive disease and death had not regained their virulence, since the tubercle bacilli recovered from the lesions were no different in their cultural characteristics or pathogenicity for experimental animals from typical BCG strains. The explanation probably lies in a peculiar absence of resistance in these particular subjects. It has also been observed in experiments on guinea pigs in which silicosis has been artificially produced that subcutaneous BCG infection seemed capable of inducing progressive pulmonary disease (Vorwald and others, 1954).

Various special problems complicate the preparation, distribution and adminis-

tration of BCG and necessitate careful and intelligent planning and supervision. The vaccine must be standardized both as to numbers of viable organisms and their degree of attenuation; it must be refrigerated and used within a two-week period in order to insure viability, except where freeze-dried preparations are used; bacteriological safety testing also presents difficulties where the interval from manufacture to use is so short. Vigilance is required to avoid contamination of cultures with virulent tubercle bacilli.

Current practice in vaccination is to first do a tuberculin test and limit vaccination to those negative to 10 TU of tuberculin, except that prior testing is unnecessary in newborn infants. Vaccine is administered in the deltoid region by the intracutaneous or multiple puncture technic, 0.1 ml. being used if the intracutaneous method is chosen. Over a period of several weeks a small nodule or ulcer develops at the site and slowly heals in the course of a few more weeks. Occasionally, some enlargement of the axillary lymph nodes appears but this usually subsides without intervention. On retesting after six to eight weeks the reaction is usually positive, although the degree of hypersensitivity is not great. Over 90 per cent of conversions can be obtained under favorable circumstances. Sensitivity tends to wane markedly with the passage of time and the question of whether to revaccinate those who have reverted has not been answered.

Opinions of authorities on the usefulness of vaccination range all the way from strong (and sometimes uncritical) enthusiasm to equally strong condemnation. Opponents point to the fact that tuberculosis mortality has fallen as rapidly in some regions where it has not been used as in any where it has. They are skeptical of the ability of an agent generally administered in childhood, the effect of which in inducing tuberculin hypersensitivity is impermanent, to affect materially the mortality in older persons who now experience the highest death rates.

Much of the argument centers about the indications for vaccination. It has been pointed out (Palmer and Shaw, 1953) that in four areas where BCG was applied on a large scale the effect in the next few years was very small because a great majority of new cases and deaths occurred among those already infected prior to the vaccination program and hence ineligible for vaccination, rather than among either the vaccinated or unvaccinated nonreactors. The prevailing opinion at present seems to be that in the United States general vaccination is not advisable but vaccination of persons with special risk is desirable; these may include students of medicine and nursing, persons in household contact with tuberculosis who are still tuberculin negative and infants in high-risk groups as, for example, Negroes in communities with a high Negro mortality. On the other hand, in countries where economic resources simply do not permit the use of other control measures such as segregation of active cases in hospitals, BCG has been employed on a wholesale scale since the end of World War II. These are in general the countries where tuberculosis mortality is still high and where nearly everyone will be exposed to natural infection during his lifetime, in contrast to those areas where it appears likely that only a minority will be so exposed.

**Control.** The elements in a sound control program will be based on all that is known of the clinical aspects, bacteriology, pathogenesis and epidemiology of the disease.

Perhaps the surest way to reduce tuberculosis is through general improvement



in the economic and social welfare of the community. While this is beyond the specific responsibilities of the physician and health officer, they can throw their influence into the demand for better living conditions. Substandard housing, with its attendant crowding of families, deficiency of sunlight, poor ventilation, lack of facilities for cleanliness and lack of recreational opportunities is a potent factor which can be attacked through slum clearance and the substitution of good dwellings subsidized by government if necessary. In the field of industrial hygiene, good working conditions, the limitation of working hours and the provision of adequate pay are important. Much can be done toward improving the nutrition of the community. Adequate assistance to the needy is essential.

Specific measures aimed at the control of tuberculosis are those which will enhance specific resistance, foster early diagnosis, prevent spread of infection and provide effective treatment and rehabilitation of patients. These activities are the responsibility of the physician, official public health agencies and the voluntary tuberculosis associations working in close and friendly cooperation and, in a larger sense, of the whole community.

Early diagnosis involves all of the agencies listed above. It begins with alertness on the part of the physician to this disease and knowledge of its clinical character. Provision of clinical roentgenographic and bacteriologic facilities is an essential responsibility of the health department.

It is not enough to diagnose properly the suspects who present themselves to the physician. Certain groups in which the prevalence of tuberculosis is known to be high must be systematically searched for unsuspected cases. Of these, the most important are the persons exposed within the family to known cases of tuberculosis, all of whom should be examined at least roentgenographically. The detailed methods of examination and frequency of repetition of such examinations will depend on the contact's age, the status of the family and various clinical or epidemiologic factors. Mass case-finding methods should not lead to the neglect of contact examinations, which have always been the most efficient means of case finding in terms of number of cases discovered per unit of persons examined. Such cases may represent either persons infected by the already known case or hitherto undiscovered sources of infection.

Surveys, by means of roentgenograms, tuberculin tests and bacteriologic methods, of population groups in which there is evidence for an excessive incidence of tuberculosis may be indicated. Such groups include operatives in some industries, inmates of institutions (especially mental hospitals and prisons) and relief recipients. Routine roentgenographic examination of all patients admitted to hospitals for illnesses other than recognized tuberculosis has been shown to be a fruitful method of case finding. There are other population groups as, for example, school-teachers, who should be routinely x-rayed annually because of the public health importance of finding tuberculosis among them. A roentgenogram should be a routine part of the prenatal examination since it is in infancy that the most urgent necessity of protection against exposure exists. Both factors (excess incidence and hazard to the public) are indications for the annual examination of nurses and other personnel involved in medical care. Roentgenograms should be routinely taken of military recruits and, where possible, of applicants for industrial employment.

For groups at special risk, an effective means of medical supervision from the standpoint of tuberculosis diagnosis and control is to do routine periodic tuberculin tests on nonreactors. In this way, conversion can be detected and the converters closely observed by roentgenographic and other methods for the development of early disease. Detection and observation of converters is now widely applied in medical and nursing schools and has even been tried on a community-wide basis (Gedde-Dahl, 1948). Among younger school children, testing programs with roentgenographic observation of positives and converters and with intensive search for household sources of infection has been tried with varying success; Wood and Mantz (1954) suggest that it may be a productive case-finding method.

For the general population, the value of mass roentgenographic surveys is fairly well established. They bring to light considerable numbers of unreported cases. While many of these are not of clinical importance, this method gives the best opportunity to discover active minimal disease at a stage where prospects of arrest and rehabilitation are brightest. A rise in the reported percentage of minimal cases, coinciding with the wide introduction of this procedure, has been noted. The "yield" of active cases from surveys has averaged a little under 1 per 1,000 persons examined. Mass surveys may be useful in stimulating public support for other elements in a tuberculosis control program such as provision of sanatorium beds, and they have educational value. To be effective, they must be properly planned, preceded by an educational campaign and followed by competent, long-continued medical observation and treatment of the discovered cases and suspects. Many surveys have failed in these respects. Disadvantages of mass surveys are their expense, their failure to reach the entire population, and the possible creation of a sense of false security among individuals receiving negative reports. It should be emphasized that mass surveys are only one component of a tuberculosis control program.

Once a diagnosis of tuberculosis has been made, every case should be promptly reported to the health department, whose responsibility it is to keep an up-to-date register of all known cases in the community. Without such records it is obviously impossible for the health department to furnish assistance in securing hospitalization, follow-up of the case and examination of contacts. Furthermore, complete reporting is essential, regardless of the individual patient's need for health department services, in order to assess the extent of the problem and the adequacy of community facilities for control. The public health nurse has an important role, through periodic visits to the patient's home, of educating the patient and his family concerning the disease and precautions to avoid transmission of infection; arranging for and encouraging examination of contacts; and arranging for hospital admission. She may also carry out tuberculin tests, collect sputum for examination and bring to the attention of the physician and of social agencies economic and social problems of the family.

Since silicosis predisposes to tuberculosis, excessive inhalation of silica dust in such occupations as quarrying and foundry work should be avoided through proper industrial hygiene practices. While this hazard has been greatly reduced in the United States, men who have sustained exposure over a period of years should be roentgenographically examined. Diabetics should also receive such examinations.

One of the major achievements in preventive medicine in the United States has



been the control of bovine tuberculosis. This has resulted from two measures: the pasteurization of milk supplies and the removal of tuberculous milch cows by a nationwide program of tuberculin testing of herds, with slaughter of infected animals. The latter measure has reduced the reactors to a fraction of 1 per cent. Extrapulmonary lesions in the human population, particularly cervical and mesenteric lymphadenitis, which were once common, have declined more rapidly than pulmonary tuberculosis. These types of disease are considered on the basis of bacteriologic studies to be frequently the result of infection with bovine tubercle bacilli, presumably via ingestion of infected milk.

Despite the success of the campaign, it is evident that tuberculosis in cattle has in no sense been eradicated or permanently brought under control. It is as capable as ever of spreading rapidly through herds and can be kept down only through constant maintenance of the program of testing and removal of reactors. The cost to the farmer and to government of this program is large. In some countries where such a program is not in effect, where pasteurization is limited to larger dairies and where the public is not accustomed to boil milk human tuberculosis of bovine origin is still important.

Segregation and treatment of patients in sanatoria and the role of specific drugs have been discussed under therapy. A separate section is devoted to vaccination.

**The Outlook.** Long before World War II, it was predicted (Frost, 1937) that tuberculosis would be ultimately eradicated in this country, barring major disaster. The war brought temporary disaster, and in countries whose civilian populations suffered heavily a marked rise in mortality occurred promptly. Immediately after the war, however, the downward trend was resumed and has been accelerated since the introduction of specific drugs. There is no room for complacency for it has been repeatedly pointed out that morbidity has not declined nearly as rapidly and that there remain large numbers of unknown active cases in the population. Nevertheless, if the vigor of our efforts is not permitted to wane the outlook appears bright for control in the near future, to a point where for the first time in the history of western civilization tuberculosis will be an insignificant problem.

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# 2

## AIR-BORNE INFECTION

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### MODES OF TRANSMISSION OF RESPIRATORY DISEASES

**Introduction.** Air-borne infection and contact infection have long competed for scientific favor as the predominant mode of spread of respiratory diseases. The pendulum of interest, first in one and then in the other, has swung sometimes to extremes. It is yet to be stabilized.

Air-borne infection is an established reality in the laboratory, both in experimental animals and in human subjects. It is now well recognized as a serious hazard to laboratory workers. It is clearly important in the pulmonary mycoses and probably in pulmonary tuberculosis. It apparently plays some role in the occurrence of certain residual cross infections in pediatric and contagious disease wards when isolation precautions to prevent contact spread are rigidly maintained. The severe epidemics of respiratory disease and streptococcal infections that occur among military recruits may be partly air-borne. With respect to the common cold, influenza and the common respiratory diseases that afflict the general population, there are almost no data to determine which mode of spread is dominant but the weight of scientific opinion presently favors contact infection.

Exact delineation of the relative importance of these two modes of spread and the conditions under which one or the other may occur is essential to the development of sound control practices since the approaches to the two problems are quite different. The prevention of air-borne infection is a problem for the environmental engineer, while the prevention of contact infection is a problem for the health officer, the public health nurse and the health educator. The former is amenable to the mass approach, utilizing the principles of air sanitation; the latter is an individual problem of personal hygiene.

The increasing interest in air as a possible vehicle of infection has resulted in a large scientific literature dealing with such problems as methods of sampling air (Bourdillon and others, 1948); the characteristics of infectious particulate aerosols (Rosebury, 1947; Bourdillon and others, 1948); the penetration and filtration of particles in the respiratory tract (Brown and others, 1950); and methods for both natural and artificial contamination of the air (Rosebury, 1947; Bourdillon and others, 1948). Numerous techniques have been developed for controlling infectious micro-organisms in the air, such as ventilation, ultraviolet irradiation, disinfectant vapors and dust suppression (Subcommittee for the Evaluation of Methods to Control Air-borne Infections, 1947; Subcommittee on Air Sanitation, 1950). While

the science of air-borne infection has yet to provide a solution to the control and prevention of the respiratory diseases in the general population, some practical applications of limited scope have been developed.

Probably more important is the accumulated knowledge regarding mechanisms of respiratory tract infection. This is basic to whatever control measures are eventually developed. Furthermore, it is basic to one phase of the military science of biological warfare, the potentialities of which only the future can determine.

**Definitions.** Much confusion and some controversy have arisen through the use of unnecessarily vague and ill-defined terms. It is common to hear the term "the air-borne infections" applied loosely to the acute respiratory and contagious diseases, although these are known to be spread, in many circumstances, by contact. Pulmonary tuberculosis is usually referred to as a "contact" disease, although increasing evidence is accumulating that it may be primarily an air-borne infection.

The portal of entry of the infectious agent is usually accepted as "the respiratory tract" without distinguishing the exact locus where the agent first invades the tissues. The manner of exit of infectious material from the patient is usually stated to be "the respiratory secretion" without clear distinctions between saliva, sputum or nasal discharges.

To avoid confusion and to provide for as orderly and as precise a discussion of the subject as possible, the following definitions are offered:

*Respiratory infections* include those infectious diseases in which the primary pathological process is in the respiratory tract and, in addition, those systemic diseases in which the portal of entry is through the respiratory tract.\*

*Portal of entry* is the exact locus where the infectious agent first invades the tissues, which may be anywhere from the nasal mucous membrane down to the alveoli.

*Routes of transfer* include four different mechanisms:

1. *Contact*, transmission directly, as in kissing, or indirectly by contaminated hands, toys, surgical instruments, or other material objects.
2. *Droplets*, transmission directly by projection onto the conjunctivae and the face, or into the nose and mouth.
3. *Droplet nuclei*, transmission indirectly by inhalation of the small residues which result from evaporation of droplets and which remain suspended in air of enclosed spaces for long periods of time.
4. *Dust*, transmission indirectly by inhalation or settling of larger particles which arise from secondary reservoirs of infection on floors, clothes or bedding and which remain suspended in air for short periods of time.

While a precise distinction between these four routes of transfer may not always be possible, each constitutes a different mechanism for which different control procedures must be designed.

Most confusion has arisen over whether droplet infection should be considered a form of air-borne infection or a form of contact. In a limited sense, droplets actually travel a short distance through the air, but in a broader sense they succeed in

\* Another group of infections which may be spread either by the contact or the air-borne routes are the surgical wound infections. These are discussed only casually in this chapter.



transmitting infection only between persons in close association. Furthermore, none of the engineering devices of aerial disinfection or dust suspension has any appreciable effect on droplets. The control of droplet infection depends on the promotion of personal hygiene and individual protection as with the control of contact. Therefore, from a practical and realistic point of view, *contact infection* will be defined to include droplet infection, and *air-borne infection* will be restricted to transmission by droplet nuclei and dust.

**History of Changing Concepts: Air-Borne vs. Contact Infection.** The history of the competition between contact and air-borne theories for scientific favor may be roughly summarized in five periods:

<u>Period</u>	<u>Approximate dates</u>	<u>Attitude toward air-borne infection</u>	<u>Predominant ideas</u>
1	Prior to c. 1890	Popular	Miasma and malaria
2	c. 1890 to c. 1934	Apathy	Contact and droplet infection
3	c. 1934 to c. 1945	Expectation	Droplet nuclei and dust infection
4	c. 1945 to c. 1950	Disappointment	Failure of practical applications
5	Since c. 1950	Guarded concern	Tuberculosis, laboratory infections, biological warfare

**FIRST PERIOD.** From earliest times to the end of the nineteenth century air was popularly conceded a most important role in the occurrence of epidemics. The concept of miasma (noxious vapor) and malaria (bad air) imply air-borne infection. These were applied indiscriminately to respiratory, enteric and arthropod-borne diseases alike. As distinguished an epidemiologist as William Farr ascribed the great epidemic of cholera in London in 1849 to miasmata diffusing from the Thames River (Farr, 1885). He demonstrated a remarkable correlation between cholera mortality and elevation above Trinity high water mark to support his contention.

**SECOND PERIOD.** With the advent of bacteriology, early findings first supported the air-borne theory, but with later findings general scientific opinion swung progressively toward a predominant interest in contact and droplet infection. Following Pasteur's early demonstration of bacteria in air, Lister introduced carbolic acid sprays into his operating room on the assumption that air was the chief cause of surgical sepsis. It was soon found, however, that with strict aseptic technics, the corrosive aerial sprays were unnecessary. Thus, the spectacular results of aseptic surgery disproved Lister's assumption and established the pre-eminent importance of contact in wound infections.

These aseptic technics were soon applied, first in Europe (Chapin, 1912) and then in the United States, to the care of patients with acute contagious diseases. The immediate success of the use of cubicles and strict isolation precautions in the care of such patients made possible the transformation of pesthouses to modern isolation hospitals and permitted the rapid development of hospital pediatrics. The conclusion that contact was the dominant mode of spread of acute contagious diseases was unavoidable.

These dramatic discoveries overshadowed the careful studies of the bacterial contamination of the air which were proceeding concurrently. Fluegge in Germany, and many others in Europe and the United States showed that certain pathogenic bacteria could be recovered from the air and the dust of inhabited places. Tubercle

bacilli were recovered regularly when culture plates or animals were exposed within a few feet to the direct coughing of tuberculous patients. Pus-forming organisms were isolated from surgical wards and even from operating rooms. After the contamination of the mouth with *B. prodigiosus* (*S. marcescens*), the organism could be recovered from the far corners of a large room or even shown to travel on air currents down corridors and up two flights of stairs. It was believed, however, that most pathogenic bacteria either rapidly died or lost their virulence when exposed to air. Furthermore, the concentration of pathogens recovered from air, except within the range that moist droplets of saliva or mucus could travel from the mouth, was exceedingly low. The weight of scientific opinion, including such workers as Fluegge, swung strongly away from air-borne infection toward the importance of contact and droplets (Chapin, 1916).

A great leader of the trend was Dr. Charles V. Chapin, Superintendent of Health, Providence, Rhode Island, from 1884 to 1931. He studied the cases of communicable diseases occurring within his jurisdiction. He showed that they were concentrated among families, but only rarely spread to adjoining families in the same or neighboring houses. From this he concluded that contact must be much more important than air-borne infection. He followed closely the rapidly expanding scientific literature in Europe and in this country and in 1910 wrote a critical treatise "Sources and Modes of Infection" in which he summarized the available evidence and argued that the force of the epidemiological evidence strongly supported contact and droplet infection as dominant for most respiratory infections. Chapin, however, specifically excepted pulmonary tuberculosis in which he admitted that air-borne infection might be important.

Through his writings and leadership in the American Public Health Association he discouraged terminal fumigation, then a popular practice, and instead he promoted good personal hygiene and simple isolation technics. He built in Providence the first modern isolation hospital in this country and established a pattern which was copied on a national scale. His persuasive logic dominated epidemiological thought and general public health practice in the field of communicable disease control in the whole United States. His influence is still felt strongly today.

THIRD PERIOD. For a quarter of a century from 1910 to 1934 interest in and investigation of air-borne infection lagged. Then Wells (1934) challenged the generally accepted principles and conducted some relatively simple experiments in which he rediscovered and extended the largely ignored findings of earlier workers. He sprayed a variety of bacteria and viruses into a closed chamber and demonstrated that they remained suspended in a viable and infectious form for hours and even days. He proposed the term "droplet nucleus" for the tiny bacteria-laden particle that results from drying of the droplets which emanate from the mouth. He showed that these droplet nuclei, which may remain suspended in air for hours, are highly susceptible to the lethal effect of ultraviolet irradiation. He initiated field trials with ultraviolet lights in the attempt to control epidemics of communicable diseases in schools and cross infections in hospital wards.

Following Wells' original contribution, interest in air-borne infections revived. It was recognized that cross infections on communicable disease and pediatric wards remained at least a minor and occasionally were a major problem in spite of presumably adequate isolation precautions. A certain low but still serious residue of



surgical wound infections occurred without known breaks in aseptic techniques. The question was raised whether or not air-borne infection was an important factor in the occurrence of epidemics of contagious disease in centralized schools and of acute respiratory disease and beta hemolytic streptococcal infections among military recruits. Following Wells' example, ultraviolet irradiation was applied widely in attempting to control these problems (Subcommittee for the Evaluation of Methods to Control Air-Borne Infection, 1947; Subcommittee on Air Sanitation, 1950).



From Moulton, F. R., *Aerobiology*.

**Fig. 2-1. A violent sneeze completed.**

Over 40,000 particles are here shown. The eyes are characteristically closed. A few droplets may be seen coming from the nostrils.

The development of serological methods for typing beta hemolytic streptococci provided a new tool for studying air-borne infection. Applied first in England and later in this country, it was found that the air, the dust, the blankets, and in fact the total environment of hospital wards and military barracks may become grossly contaminated with one or more strains of specific streptococci. Certain types of patients, particularly those with purulent discharges such as otitis media, sinusitis, septic skin infections, or merely carriers with a strongly positive nasal culture have a peculiar capacity to disperse large numbers of streptococci. These findings led to the development of dust suppressive measures on the assumption that the gross contamination of the dust in such environments became a primary reservoir for subsequent human infections. These were applied in large scale field trials in military populations during and subsequent to World War II.

An intensive search for other methods of disinfecting air was made. A wide variety of chemical substances in the form of aerosols and vapors were tested and found to have bactericidal effects of varying degrees and markedly varying toxicity and corrosiveness. Of these substances, the relatively nontoxic glycols, particularly

tri-ethylene glycol, received greatest attention in the laboratory and in limited field tests.

Throughout the period from 1934 to 1945 the revival of interest in air-borne infection led some of the more enthusiastic workers to predict that the application of engineering methods of air sanitation would eventually lead to the same successful control of the respiratory and contagious diseases as had followed the application of engineering technics to the control of the enteric diseases. In many circles it became the fashion to refer to the respiratory and contagious diseases as "the air-borne infections."

FOURTH PERIOD. Despite these extensive studies pointing toward the possible importance of air-borne infection, the results of practical field trials with the newly developed engineering devices for aerial disinfection were generally disappointing, except in a few limited types of environments.

Ultraviolet lights were installed in operating rooms, and in pediatric and contagious disease wards. Further reductions in the already low incidence rates of cross infections were reported in several well-controlled studies. In other studies, slight, if any, benefit was achieved. The guarded conclusion was justified that this procedure has limited application in such environments, when the lights are properly installed and maintained. It is clear, however, that they are not a substitute for strict isolation precautions.

Ultraviolet lights had extensive tests in primary and secondary schools for control of the acute contagious diseases. The report of Wells' early experiment in the Germantown school was impressive. An epidemic of measles spread more extensively through the unirradiated upper grade class rooms than through the irradiated lower grades, in spite of the much larger number of susceptibles among the younger children. Repetition of this dramatic result, however, has not been reported, either by Wells or others. In subsequent studies, only slight effects from the irradiation could be discerned, such as the prolongation of the epidemic, changes in epidemic patterns, and slight differences in attack rates among susceptibles. While these effects suggest that the ultraviolet light may partially reduce classroom spread of infection, they are of only theoretical interest. The extensive experience of numerous studies is sufficient to warrant a confident conclusion that the presently available methods of ultraviolet irradiation in schools are not practical for controlling contagious disease epidemics. Furthermore, even if they were effective, there are valid reasons against their use. The only effect that could be expected would be to postpone acquisition of infection to older ages or adulthood when the consequences of certain of these diseases are more serious.

The use of ultraviolet lights in naval barracks resulted in reductions of approximately 20 per cent in the incidence of acute respiratory diseases. While the results are quite variable, there was sufficient consistency in the findings over a period of six consecutive years to indicate that air-borne infection played at least a partial role in the problem. The methods used, however, failed to prevent the introduction and epidemic spread of common respiratory diseases, primary atypical pneumonia, influenza and beta hemolytic streptococcal infections in the irradiated barracks.

These trials did not provide a definitive test of the importance of air-borne infection in such environments. Only a 50 to 75 per cent reduction in bacterial contamination of the air was achieved. The failure to effect a greater reduction in



disease may have resulted from inadequate sterilization of the air or from the possibility that contact and droplet infection is the dominant mode of spread. Only when a much greater disinfection of the air is attainable will this question be answered.

The oil treatment of floors and bedding in military barracks was tested extensively with slight if any beneficial effects. Although this simple and readily applied procedure achieved a substantial reduction in bacterial contamination of air, particularly during bed making and floor sweeping, only inconclusive or no reductions in the incidence of epidemic acute respiratory disease and hemolytic streptococcal infections were reported. These studies clearly indicated that dust suppressive measures alone were insufficient for controlling epidemics of respiratory disease among recruits.

Technical problems in the dissemination and maintenance of bactericidal concentrations of glycol vapors in large occupied spaces precluded adequately controlled field trials. Limited tests in hospital wards and single barracks buildings indicated that a substantial reduction in aerial bacteria could be achieved, particularly if dust suppressive measures were carried out concomitantly. The epidemiological observations have been insufficient to warrant valid conclusions (Krugman and Ward, 1951).

Several attempts were made to use glycol vapors in ventilating ducts and air conditioning systems in large offices or industrial establishments to control the common cold. Serious technical limitations were encountered. In those studies where epidemiologically controlled observations were attempted, no benefit resulted. Such negative findings might well be anticipated since workers have multiple daily opportunities to acquire infections outside of working hours.

Thus, the hopes and predictions that the engineering methods of air sanitation would find wide general application failed to materialize. The impressive bactericidal effects of ultraviolet light and glycol vapors under laboratory conditions were less impressive in the field. They could be installed only in certain types of environments. Infections occurring in test populations outside the treated spaces could not be prevented and were difficult to evaluate. It became apparent that these methods had only limited application to highly specialized and regimented populations, such as contagious disease and pediatric wards and certain types of operating rooms where contact infections could be rigidly controlled and where residual air-borne infections remained important. Even in these environments the methods of air sanitation have had only limited acceptance, presumably because of the cost of their installation and maintenance and because during the period of their development the serious consequences of cross infections have become minimized due to the therapeutic and prophylactic use of antimicrobial drugs and gamma globulin.

While substantial evidence was accumulated that air-borne infection did occur at certain times and places, the question of its relative importance compared with contact and droplet infection remained unanswered; it can be expected to vary with different specific diseases. The definitive experiment to test its importance in large population groups for any one infection has yet to be performed. Certainly the present evidence accumulated is insufficient to justify discarding Chapin's views or to support the enthusiastic claims of the commercial exploiters of ultraviolet lights and glycol vaporizers. The term "contagious," meaning contact, remains a more appropriate adjective than "air-borne" to describe the common respiratory infections.

**FIFTH PERIOD.** While the hopes for broad practical application of the methods of aerial disinfection in the control of respiratory diseases failed to materialize, limited applications were discovered. Improvements in existing methods and new technics can be anticipated. Therefore, the basic principles of the present methods should not be ignored. Furthermore, the increasing recognition of the critical importance of particle size in the penetration and retention of particulates in the respiratory tract has opened new areas of interest in air-borne infection. Among these are pulmonary tuberculosis, certain pulmonary mycoses and accidental laboratory infections. The principles involved in these new areas have important application in any consideration of the potentialities of biological warfare.

## METHODS OF CONTROLLING AIR-BORNE MICRO-ORGANISMS

Bacterial contamination of the air may be controlled by four general methods: (1) mechanical ventilation; (2) ultraviolet irradiation; (3) disinfectant vapors; and (4) dust suppression.

**Ventilation.** The simplest of all measures for removing contaminants from enclosed spaces is natural ventilation from open windows. This is a generally accepted practice as part of terminal disinfection and is still advocated as a routine measure in contagious disease wards, particularly in Great Britain. The limitations of such a procedure are so obvious that it cannot be considered an effective measure to control air-borne infections.

Similarly, the use of forced ventilation and air conditioning is inadequate. In occupied spaces the production of new air-borne bacteria resulting from normal human activity is so great that the rate of air change necessary to reduce the contamination substantially is uneconomical and causes unpleasant draftiness. Furthermore, the almost universal practice of recirculation of air in ventilating systems may serve to disseminate air-borne pathogens (Yaglou and Wilson, 1942).

Under specialized conditions the use of controlled air currents, either alone or in conjunction with physical barriers, filters, precipitators, or other mechanical means of removing particulates from the air may have limited applications. In operating rooms, surgical dressing rooms, nurseries for premature or newborn infants and other specialized environments where the consequences of infections may be serious, the investment in expensive and carefully designed air conditioning systems may well be justified.

In research laboratories dealing with highly infectious agents, the risk of air-borne infections to personnel and among experimental animal colonies is now clearly demonstrated. Here controlled ventilation, often augmented by other means of aerial disinfection, is essential.

**Ultraviolet Irradiation.** The disinfectant action of ultraviolet light has long been known and has been accurately quantitated. Wave lengths in the range of 2,500 Ångstrom units are most bactericidal. The development of the low pressure mercury vapor lamp which emits its maximum radiation in the wave length 2,537 Å.U. has made possible practical and reasonably economical devices. Under laboratory conditions, using finely atomized suspensions of bacteria or viruses, practical intensities of irradiation induce a rate of removal equivalent to 100 or more air changes per hour. Under field conditions similar rates of reduction are not achieved because the



bacterial contaminants are of varying size, from small droplet nuclei to large dust particles. Naturally-occurring bacteria in the air may have a coating impermeable to the bactericidal rays. Nevertheless, substantial reductions in bacterial air counts of 50 to 75 per cent have been repeatedly achieved under the rigorous conditions of crowded naval barracks (Moulton, 1942).

Certain practical limitations have been encountered in the utilization of ultraviolet irradiation for the control of air-borne infection in occupied spaces. Germicidal intensities are injurious to the human skin and conjunctivae, thus requiring that the radiation be confined to the upper air of rooms above the head level. Skilled engineering services are necessary for the supervision of each installation to insure maximum intensities in the upper air and at the same time to avoid reflections from ceilings, walls or other surfaces that may "burn" the occupants. The use of ultraviolet absorbent paints may be necessary. Numerous types of carefully designed fixtures and practical photometers to measure intensities are commercially available. Continuing supervision of each installation is necessary for regular cleaning of the lamps and their reflectors and for the testing and replacement of tubes showing diminished output.

In pediatric wards and operating rooms, carefully placed light screens or "curtains" may be installed at the entrance to rooms, or cubicles or around the operating site. Such procedures can be used safely only when patients are rigidly controlled and when all medical and nursing personnel are strictly indoctrinated and disciplined as to the dangers of direct exposure. That these problems are not insuperable is demonstrated by the fact that numerous installations have been in service for long periods.

More serious limitations to the generalized use of ultraviolet irradiation in occupied spaces are theoretical in nature. Since the intense rays must be confined to the upper air, only those droplet nuclei which circulate through the upper air can be disinfected. In occupied spaces this circulating air is continuous and quite rapid, but at best only a partial reduction in bacterial contamination can be expected. Successful use of ultraviolet irradiation, therefore, depends on the as yet unproved premise that infectious disease fails to spread in an inclosed space when the concentration of the air-borne pathogens is lowered below a certain threshold. Furthermore, since the rays are less effective against larger particles, little, if any, effect can be expected against dust-borne infections (Subcommittee for the Evaluation of Methods to Control Air-Borne Infections, 1947; Subcommittee on Air Sanitation, 1950).

**Disinfectant Vapors.** Many chemicals have been shown to have marked bactericidal action when dispersed in air. These include the halogens, hypochlorites, lactic and other hydroxy acids, hexylresorcinol, and the glycols (Bourdillon and others, 1948). Of these, the glycols, particularly tri-ethylene glycol, appear to be the most practical because of their high bactericidal potency, reasonable cost, and freedom from odors, toxicity and corrosiveness.

Originally, the mechanism of action of these substances was assumed to be collisions between bactericidal particles and aerosol droplets of the disinfectant. Subsequent laboratory experiments and theoretical considerations indicate that condensation of vapor onto the bacteria-laden particles is a more satisfactory explanation, at least for the glycols.

In vitro studies show that the glycols are only moderately bactericidal in solution. Concentrations of 50 per cent or greater are needed to produce a rapid killing rate. Extremely minute concentrations of the same substance in the air, however, produce a most dramatic bactericidal effect.

The explanation for this apparent difference lies in the low vapor pressures of the glycols. To be effective, the saturation in the air must exceed 50 per cent. Since air-borne bacterial particles are necessarily small and contain at least some water, and since the glycols are highly hygroscopic substances, an equilibrium between the concentration of glycol within the particle and in the surrounding air is rapidly reached. Depending on the relative humidity, this equilibrium concentration may equal or exceed that which is rapidly bactericidal in solution. If the humidity is too high the equilibrium concentration is too low. In very dry atmospheres, bacterial particles contain so little water that insufficient glycol condenses. At intermediate humidities, roughly 20 to 50 per cent, effective concentrations are rapidly attained. It is a fortunate circumstance that the relative humidity of many types of occupied space in winter months usually falls within this range.

Glycol vapors have one distinct advantage over ultraviolet irradiation because they may permeate the entire atmosphere of an enclosed space. Thus, pathogens emanating from an infected individual as small droplets from the mouth or nose begin to absorb the vapor molecules immediately and, in the process of drying, bactericidal concentrations are built up within the droplet with great rapidity. Therefore, glycol vapors can be expected, at least on theoretical grounds, to induce a greater reduction than ultraviolet irradiation in the concentration of fresh infectious nuclei (Subcommittee for Evaluation of Methods to Control Air-Borne Infections, 1947; Subcommittee on Air Sanitation, 1950).

Serious limitations in the practical use of glycol vapors still remain to be overcome. As with ultraviolet light, the vapors have little effect on larger or dust particles, presumably because they are coated with substances that neutralize the effect or because dried bacteria are resistant.

Another difficulty that has yet to be solved on an economical basis is maintenance of adequate saturations of vapor in occupied spaces. The glycol output of many commercially available vaporizers is grossly inadequate. The hourly and daily variations in the indoor temperature and relative humidity resulting from occupancy and outdoor conditions require a method of vaporization that will respond promptly to a variable demand. One simple procedure for insuring continuous bactericidal concentrations is the maintenance of a slight fog in the room at all times, which means that the saturation of the vapor is being approached or exceeded (Subcommittee on Air Sanitation, 1950).

**Dust Suppression.** The control of the dust and lint in the air that arises from the floors, blankets, bedding and clothes during normal activity is based on the principle of making these particles sticky. Light paraffin or spindle oils are quite satisfactory. Unvarnished soft wood floors, such as exist in many types of military barracks and schools, may be treated with a saturation dose of oil, thereby effectively laying the dust for several months. Hardwood floors require less oil but more frequent treatments. Painted concrete, waxed or linoleum floors should not be oil-treated but these are usually less dusty and the daily use of oiled sweeping compounds is helpful.

The oiling of floors darkens the surfaces, increases slightly their slipperiness, and



may soil the feet, shoes, trouser cuffs, and clothes of occupants. But these minor disadvantages are more than overcome by the greater ease of routine housekeeping and marked reduction in dustiness.

Wholly practical methods are available for the oil impregnation of blankets, bedding and certain types of clothing (Puck and others, 1946; Loosli and others, 1946). By adding a stable emulsion of a purified paraffin oil, made with a neutral detergent, Triton NE, to the final rinse in the laundering process any desired deposition of oil on the fabric can be attained. A concentration of approximately 2 per cent by weight makes no appreciable change in the appearance or feel of the material, yet gives it remarkable dust and bacteria-holding properties. Woolen fabrics retain these properties for many months, even after subsequent washings. Cotton fabrics require re-treatment.

In military barracks or hospital wards where floors and bedding have been oil-treated, substantial reductions of 90 per cent or greater in the bacterial contamination of air have been consistently achieved. The greatest effect is noticed during sweeping and bed making, when in untreated wards gross contamination regularly occurs.

Although repeated studies of dust suppressive measures in the control of respiratory diseases have largely failed to demonstrate consistent benefits, oiling procedures have recognized advantages from the point of view of "good housekeeping." Furthermore, since neither ultraviolet light nor glycol vapors have an appreciable effect on dust-borne bacteria, dust suppression should be utilized whenever these other methods of aerial disinfection are employed.

## RETENTION OF PARTICLES IN THE RESPIRATORY TRACT

The relation between the size of inhaled particles and the depth of their penetration and retention in the respiratory tract has explained many confusing problems in the epidemiology and pathogenesis, not only of industrial hazards such as silicosis, but also of air-borne infections (Hatch, 1942; Brown and others, 1950). Furthermore, effective inhalation therapy with antimicrobial and other drugs depends on this principle.

Theoretical calculations applying established physical principles to the known dimensions of the respiratory tract and experimental studies using a variety of different techniques, including radioactive isotopes, have led to essentially similar results (Wilson and LaMer, 1948). They show that the respiratory tract is an exceptionally good filter, considering the volume of air which passes through it.

Particles larger than five microns in diameter are almost completely removed in the nose and upper respiratory passages. Below five microns in size progressively increasing proportions of inhaled particles reach the terminal bronchioles and alveoli. In the range of one micron from 50 to 60 per cent penetrate to the alveoli and are trapped there. Below this range, alveolar deposition again decreases because more particles are exhaled. In the submicroscopic range below .25 micron an increase in retention is theoretically expected because Brownian movement comes into greater action.

The fate of inhaled particles larger than five microns is quite different from that of the smaller particles. Those that impinge on mucus overlying ciliated epithelium

are wafted to the oropharynx where they are most likely to be swallowed or occasionally expectorated. Those that impinge in the anterior chamber of the nose will be wafted to the external nares. The smaller particles that are retained beyond the ciliated epithelium in the terminal bronchioles and alveoli must be removed by tissue mechanisms, principally phagocytosis. Thus, for toxic substances, such as silica, minerals, or metallic poisons, and for those pathogenic agents not normally infective through an upper respiratory portal of entry, inhalation of large particles is essentially equivalent to a slow gastro-intestinal instillation. Inhalation of particles progressively smaller than five microns becomes increasingly similar to an intratissue or subcutaneous inoculation. (See material on dust, page 1044.)

Inhalational therapy with sulfonamide drugs and penicillin utilizes these same principles. In the treatment of nasopharyngeal or sinus infections large particles 20 microns or more in diameter are indicated (Committee on Public Relations, 1950). For broncho-pulmonary infections where local deposition on the bronchioles as well as absorption into the blood stream are required, then particles of two to six microns should be used. If systemic absorption is the primary objective, particles from 0.6 to 1.6 microns are recommended.

These principles have direct application to the mode of spread of respiratory infections. For those infectious agents, such as the streptococcus and the diphtheria bacillus, which have the capacity to invade the tissues of the nose and pharynx, and for agents such as influenza virus and *H. pertussis* which invade the respiratory epithelium of the nasopharynx, the trachea and larger bronchi, no special problem arises. Air-borne particles, large and small, can reach these sites by inhalation. In contrast, those infectious agents that do not normally invade these sites, but rather infect only through the terminal bronchioles or alveoli, must be dispersed in the air in exceedingly fine particles. It is easy to visualize how infections of the upper respiratory tract can be spread as readily by direct or indirect contact as by inhalation. It is difficult to visualize how an infection, with its primary portal of entry the alveolus, can originate except by air-borne infection.

The upper limit to the size of particles that can reach the alveoli is strikingly similar to the dimensions of single bacterial cells, fungal spores, rickettsiae and the virus elementary bodies. This should not be considered as mere coincidence but rather as a fact of special biological significance. The mammalian lung is an intricate structure that has developed by the evolutionary process of natural selection. Its dimensions have been determined on the one hand by the viscosity of air and the physiological needs of respiration, and on the other hand by the obvious necessity to filter out most noxious particulate matter. The fact that the human lung successfully removes particles larger than single bacterial cells should be regarded as one of many factors contributing to the survival of the species.

Furthermore, pathogenic agents rarely exist in nature as single cells; rather they tend to grow in clumps or chains. They are almost always intimately mixed with mucus, pus, saliva, feces or other moist organic matter. This means that when they are extruded into the open environment they tend rapidly to adhere to surfaces or to inert particles of dirt, dust or lint and thereby become even larger.

Certain exceptions to this general argument should be noted. During a sneeze, myriads of small droplets are produced. The violence of this atomization may produce a fracturing of bacterial clumps leading to a dispersal of a few single cells. If



viruses are present in the sputum or saliva, some of these may well be dispersed in small particles.

Under certain conditions the environment may become grossly contaminated with pathogenic agents. For example, some nasal carriers of hemolytic streptococci and patients with streptococcal skin infections or draining wounds may disseminate prodigious numbers of bacteria. The placental tissues and postpartum discharges of sheep and cattle infected with Q fever and brucellosis contain high concentrations of the infectious agents which contaminate the local environment. The careless tuberculous patient with strongly positive sputum must disseminate large numbers of organisms into his immediate surroundings. Under such specialized conditions of gross contamination, sweeping, bed making, and other normal activity may well raise into the air an occasional small infectious particle along with a large number of big particles.

The pulmonary mycoses constitute another special situation. Here the pathogenic agents presumably exist and grow in nature. Coccidioidomycosis occurs in dry climates, histoplasmosis in areas of higher relative humidity. Both are almost certainly air-borne infections with the portal of entry in the alveolus of the lung. Single infectious spores may well be released into the air by natural processes not yet well defined.

Pulmonary tuberculosis constitutes another special problem. The locus of the primary lesion in the lung parenchyma strongly suggests the terminal bronchioles or alveolus as the portal of entry. Since the dimensions of the tubercle bacillus are approximately two by six microns, only a single cell or a very small clump of bacilli can reach this site by inhalation. A large majority of primary lesions are known to be single, which suggests that the primary complex arises from a single small particle. Wells and others (1948) have reported that in rabbits the inhalation of large particles results in none or very few pulmonary lesions, whereas the inhalation of equal numbers of small particles results in many pulmonary tubercles. Lurie and others (1950) have amply confirmed and expanded this observation. In a long series of tests they showed that the inhalation of single viable particles produced discrete tubercles in numbers equal to the estimated particles retained in the alveoli.

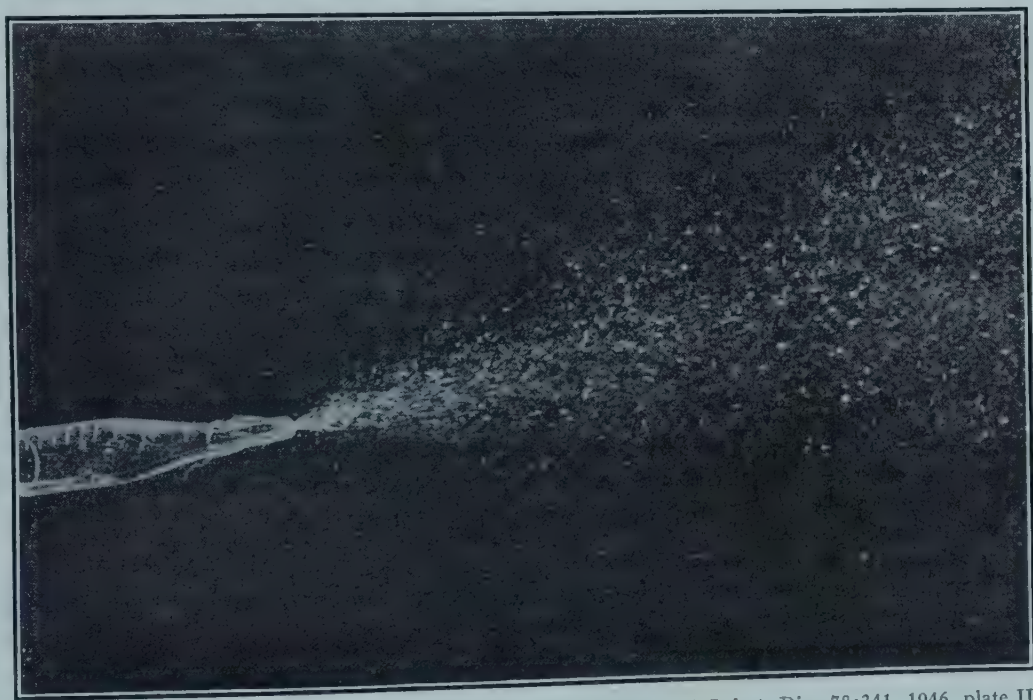
The concept that primary pulmonary tuberculosis is predominantly an air-borne infection most adequately accounts for some aspects of the epidemiology of the disease. The frequency of single primary lesions fits with the probable infrequency of very small infectious particles in the air. This in turn is consonant with the known relatively noninfectious character of tuberculosis. Some intimate household contacts may be exposed to open cases for several months without becoming tuberculin positive. Increasingly large proportions of the adult population are remaining uninfected in spite of the known numbers of sputum-positive cases at large. The initial pulmonary lesion apparently results from the occasional small particle that occurs during a gross environmental contamination or from some other as yet poorly defined mechanism that introduces single cells into the air. Thus, the concept that primary pulmonary tuberculosis may be predominantly an air-borne infection rather than a contact infection deserves serious consideration.

While these exceptions are of great importance in the epidemiology of certain specific infections, they do not negate the general conclusion that single pathogenic cells are only rarely dispersed into the air under natural circumstances. Rather, it

would seem that the human species has not been forced to contend with a wide variety of finely dispersed bacterial aerosols and, therefore, has not faced the biological necessity of developing a natural mechanism to defend against them.

Artificial circumstances present an entirely different picture. Using modern laboratory technics, many pathogenic agents may be grown in almost limitless quantities and may be dispersed into the air as single cells. When this occurs accidentally, as in laboratories, serious infections have often ensued (Sulkin and Pike, 1949; 1950).

Until recently the commonly accepted mode of transmission of these accidental infections was contact resulting from errors in technic. Much evidence supported this view. Many infections had been observed to follow relentlessly upon such incidents as the aspiration into the mouth of a virulent culture during pipetting, or the nicking of the hand during autopsy, or the jabbing of the finger during animal inoculation, or the gross contamination of the whole environment when a flask of agent was spilled or broken in a centrifuge.



From Johansson, K. R., and Ferris, D. H., *J. Infect. Dis.*, 78:241, 1946, plate II.

**Fig. 2-2. Blowing last drop from pipette.**

Numerous laboratory infections have occurred, however, in the absence of known breaks in technic, even when extreme precautions were being consistently followed.

Of special interest are the occasional explosive epidemics that have occurred in research laboratories. These have involved large numbers of persons in widely separated rooms, and have occurred under circumstances that apparently preclude direct contact (McCoy, 1930, 1934; Newitt and others, 1939; Huddleson and Munger, 1940; Huebner, 1947).

Recognition of the air-borne origin of many of these obscure infections and



unexplained epidemics developed slowly but is now generally accepted. Important in this change has been the association of accidents with certain laboratory procedures, such as intranasal instillations, centrifugation of concentrated suspensions of infectious agent, and grinding of tissues in the Waring Blendor. These procedures often produce invisible clouds of finely dispersed infectious aerosols.

Of special interest are the studies of Johansson and Ferris (1946) which showed that aerosols were produced even by routine procedures, as removing a cotton plug from a flask, transferring cultures, withdrawing a hypodermic needle from a stoppered vial, or blowing the last drop from a pipette. These studies illustrate in a graphic fashion the manifold opportunities for aerial contamination that exists in laboratories, and point to the necessity for redesigning of laboratory buildings and equipment to protect personnel working with infectious agents. In such planning, specially designed hoods with controlled air currents, ultraviolet irradiation, and disinfectant vapors all have important implications.

Thus, the recognition of the relation of size of inhaled particles to the locus of their retention in the respiratory tract has led to better understanding of air-borne disease and the mechanisms for protection. At the same time, it has led to the contemplation of its possible use for destructive purposes in warfare. The occurrence of infections among laboratory workers demonstrates the possibility that an enemy might be able to create purposeful epidemics by reproducing similar conditions. Whether such an artificially induced epidemic would be subsequently propagated by natural transmission in the population attacked is open to question. Nevertheless, the potential menace of the creation of clouds of infective particles liberated in an enclosed space by saboteurs or diffused in air currents over wide areas against large populations in open warfare by munitions cannot be ignored.

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# 3

## CONTAGIOUS DISEASES SPREAD LARGELY THROUGH FECAL DISCHARGES

Grouped together in this chapter are diseases and infestations transmissible from man to man, caused by parasites which enter the mouths of human beings with food and drink, can develop and multiply in some portion of the alimentary canal, are capable of disturbing physiological functions, and whose progeny are discharged in the feces. Their continued propagation is dependent principally upon fecal dissemination. Per contra their control is dependent upon measures included under the general designations of personal hygiene and sanitation, intended to reduce the opportunities for contamination of food and drink with fecal material. Although they have this much in common, they present a wide range of differences. The causative agents are certain species of intestinal bacteria, protozoa and helminths. Each has its own peculiar host relationships, biological requirements, potential pathogenicity, and ability to survive in the external environment. Each, therefore, has its own characteristic clinical, pathological and epidemiological pattern. From the point of view of prevention, each presents a distinct and separate problem.

### CHOLERA

Cholera is an acute specific infection of the alimentary tract due to the cholera vibrio. The onset may be with a moderate diarrhea which increases in severity, but it is much more frequently sudden with violent purging and vomiting. There are very copious, watery evacuations, the stool taking on a typical "rice water" appearance, nonoffensive whitish fluid with flakes of mucus and occasionally streaks of blood. The diarrhea is followed shortly by diffuse watery vomiting. In the more severe cases, symptoms attributable to fluid loss and toxic absorption develop, notably muscular cramps, suppression of urine and collapse. Unless the rapid dehydration is checked by the parenteral administration of fluid, the course is rapidly fatal. The patient either recovers or dies within a few days. The case fatality rate has varied from 20 to 85 per cent in different outbreaks, depending upon the completeness of reporting of cases and the availability of good medical care. In the presence of an epidemic the clinical recognition of cholera presents no difficulties. Sporadic, mild cases are more difficult to recognize. The diagnosis is made by isolating the cholera vibrio from the stool, sometimes also from the vomitus of patients. The incubation period is short, frequently from one to two days, rarely over five.

**Prevalence.** According to Hirsh: "In the nineteenth century annals of pestilence, the year 1817 stands as one charged with fatality to the human race. It was in that year there began the epidemic extension over India of a disease which had previ-

ously been known only as endemic in a few districts of the country; in that and the following year it overran the whole peninsula, in a short time it crossed the borders of its native territory in all directions, penetrated in its further progress to almost every part of the habitable globe, thus acquired the character of a world-wide pestilence, which has repeatedly since then entered on its devastating campaign and has claimed its many millions of victims."

In the nineteenth century cholera repeatedly spread along the routes of trade and travel to Europe, Asia, Africa, and America. There have been five periods of pandemic spread, during four of which it has reached the North American continent; one from 1817 to 1823, another 1826 to 1837, a third 1846 to 1862, a fourth from 1864 to 1875, and a fifth from 1883 to 1896. In 1832, it entered the United States by way of New York and Quebec and reached as far west as the military posts of the upper Mississippi. The disease occurred in 1835 and 1836. In 1848, it entered the country through New Orleans and spread widely up the Mississippi and was dragged across the continent by the searchers for gold all the way to California (1849). It again prevailed widely through this country in 1854, having been introduced by immigrant ships into New York. In 1866 and 1867 there were less extensive epidemics. In 1873, it was again introduced into the United States through the agency of the mercantile marine. It prevailed especially in the Mississippi Valley, causing a "deplorable mortality." As a result of Congressional action this epidemic was thoroughly investigated by John M. Woodworth, Supervising Surgeon, U. S. Marine Hospital Service, in 1875. His report was the basis of the maritime quarantine regulations which were subsequently promulgated in this country to prevent importation of the disease. Since then, only occasional cases at seaports have been reported.

In 1892, the great epidemic of Hamburg occurred, and cases were brought by transatlantic liner to New York but the disease failed to spread. Since the turn of the century, in spite of disordered conditions of World War I and World War II, cholera has been unable to establish a foothold in the countries of northern Europe, the British Isles, North and South America. It has been limited to southeast Asia with occasional spread along lines of travel into Asia Minor, southeastern Europe, Russia, China, the Philippines, Japan and adjacent territories (Swaroop and Politzer, 1952).

In southeast Asia the disease is continuously endemic, in certain parts of India, particularly in Bengal, the Ganges Delta region, and in central and southeast Madras. There are also areas in which it is currently endemic: in Burma, Indo-China, Thailand and the Yangtze Valley of China. At irregular intervals it propagates from these centers into the adjacent areas. That it still remains a threat to neighboring countries is illustrated by the fact that Egypt was free from cholera from 1902 to 1947. In the latter year it was introduced, prevailed widely in the lower Nile Valley, and before it again disappeared in 1948 had caused some 20,462 deaths in 3 months.

**The Cause.** Although the idea that a living micro-organism was the cause of cholera had long been suspected, it was not until 1883 that Koch discovered vibrios in the stools of cholera patients in Egypt. Later, at the Medical College of Calcutta, India, he reported finding the same kind of vibrios in the stools of every case of cholera he examined. Although elements of proof were lacking, Koch's theory received general credence and the matter was left where it stood for some years.



Confusion was caused by the fact that there are a large number of vibrio forms found in nature from which the cholera vibrio had to be differentiated.

Advance in this direction was afforded by the demonstration of the Plesker phenomenon in 1893 and later the use of the agglutination test. Although agglutination narrowed down the number of suspected vibrios, it did not sharply distinguish those which were pathogenic from those which were non-pathogenic. It took a good many years of study and research before reasonably satisfactory methods were developed for this purpose. A classification based principally upon antigenic analysis by agglutination was proposed by Gardner and Venkatraman in 1935. Their work has recently been confirmed by Burrows and others (1946). Study of the thermostable somatic antigens of a large number of strains showed that the vibrios could be divided into six immunological groups which they designated O subgroups I to VI, inclusive. All of the true cholera vibrio strains fell into group I. Four immunologic subtypes are recognized, viz., Ogawa, Inaba, Hikojima and Burrows. The potential pathogenicity of a fifth type, the El Tor vibrio, is in doubt.

Using monospecific antisera made from these subtypes, it is now possible to identify pathogenic vibrios with confidence. This is particularly true when the strains examined come from human sources. The limits within which mutations may occur in nature, producing pathogenic from non-pathogenic forms, and vice versa, is still a matter of uncertainty.

Cholera infection does not occur naturally in any animal species other than man, although a somewhat similar condition may be readily produced in very young guinea pigs and rabbits. Small laboratory animals are susceptible to the action of the endotoxin of the vibrios and to products of their metabolism when cultured material is injected intraperitoneally or given by mouth in large quantities.

Accidental infections of laboratory workers have occurred and have been fatal, but they are comparatively rare. The organism may lose its pathogenicity on repeated transfer in artificial culture.

**Diagnosis.** In the infected individual the vibrios are confined almost entirely to the gastro-intestinal tract. They are usually found in large numbers throughout its whole length. They escape from the body in stools and vomitus. The patient does not usually pass cholera vibrios in stools for more than five days from the time of first infection. Diagnosis is made by isolating the vibrios from the patient's stool or a rectal swab, occasionally also from the vomitus.

A clinical diagnosis of cholera may be presumptively supported by finding large numbers of comma-shaped bacilli on direct microscopic examination of stained preparations, or in hanging drops, of the mucus flakes from the stools. Because of the delicacy of the organism, cultivation procedures should be carried out as promptly as possible. Usually, the suspected fecal material is streaked on alkaline (pH 9 to 9.6) agar and inoculated heavily into a tube of peptone water of the same pH. Portions of suspected colonies on an agar plate are rubbed upon a slide in small pools of specific serum of proper dilution, or a pure culture suspension is added to serial dilutions of (Inaba and Ogawa) diagnostic sera incubated at 37° C for one hour and examined for agglutination (Diagnostic Procedures and Reagents, 1950).

**Survival.** Of great importance in the epidemiology of the disease is the ability of the causative organism to survive outside the human body. It has no resistant

phase. *Vibrio cholerae* dies in a few hours in the fecal specimens at room temperature. In fecally contaminated clothing it survives for one to three days in a moderately moist temperature but is easily killed by drying. Under favorable conditions of storage in a cool moist environment, vibrios may remain viable for from four to seven days on the surface of fresh fruits and vegetables. In concentrated sewage it dies in 24 hours. On the other hand, in pure water it also dies rapidly. Survival of cholera vibrios in water can be promoted experimentally. For example, vibrios will survive for some weeks in water with a concentration of 0.02 per cent salt and 1/5,000,000 peptone with pH range between 6 and 9. Analogous conditions are approached in some of the natural waters in Bengal.

**Carriers.** Studies on the mode of spread of cholera in Hamburg in 1892-1893 led Robert Koch in 1893 to an appreciation of the role of the carrier "Vibrionenträger" in disease transmission. He observed that among a number of persons who have been exposed to cholera infection the resultant cases may show the whole scale from the severest of rapidly fatal cases down to the mildest imaginable, demonstrable only by bacteriological examination. He also observed that infectious matter might be contained in the evacuations of patients immediately before and just after the acute illness, i.e., at a time when association with others was not yet or no longer regarded as dangerous. This explained why human association could propagate cholera through the medium of apparently healthy persons.

A subclinical or contact carrier, like the case of cholera, does not usually pass true cholera vibrios in stools for more than five days. In the Egyptian experience of Kamal, in 1948, in which members of the household in which a case had occurred were released from isolation after two negative stool examinations three days apart, it was found that most of the carriers had become free by the tenth day; a small percentage continued to be positive for vibrios up to the fifteenth day. The longest carrier state observed was 26 days. There is no record up to the present of an individual harboring the organism continuously for more than one month.

**Modes of Transmission.** Cholera is spread by man from place to place. It follows the lines of trade and travel. Seaports are invariably first attacked. The epidemic at Hamburg in 1892 was brought to that port by immigrants on board vessels from Russia. There are many similar instances. In 1849 many a gold hunter found another Eldorado than the one he was searching for, as cholera was dragged across the continent by the caravans seeking fortunes in California. The same thing takes place in the Indian pilgrimages to Mecca.

The cholera vibrio enters the digestive tract through the mouth. It is taken in food and drink. Infected water is a frequent medium of transference, and probably the chief vehicle of the great epidemic outbursts. Cholera, however, may be transferred from man to man directly, also indirectly by flies, fingers, food, and all the innumerable channels from the anus of one man to the mouth of another.

**Water-Borne Outbreaks.** The cholera vibrio may live and even multiply in water. Koch in his original investigations found vibrios in the foul water of a tank in India which was used by the natives for drinking purposes. It has been shown by experiment that the cholera vibrio may multiply to some extent in sterilized river water or well water; and that it preserves its vitality in such water for several weeks. In recent times vibrios have been found not infrequently in the water of wells, water mains, rivers, harbors, canals, and even sea water (the North Sea near the mouth



of the Elbe), which have become contaminated with the discharges of cholera patients. It is plain from the nature of the case that polluted water must play a very large rôle in spreading this infection.

Cholera in London in 1854; the Case of the Broad Street Pump. Cholera was prevalent in London in 1854, but prevailed with epidemic intensity in the district about Broad Street. The circumstances were studied by John Snow. His monograph on the "Mode of Communication of Cholera," which has been reprinted by the Commonwealth Fund (1936), with an introduction by Wade Hampton Frost, is a classic which every student of epidemiology should read. This focus was conspicuously circumscribed in area, and the disease was virulent, with great fatality. It was one of the earliest instances, if not the first, in which water was proved to convey a specific disease. No less than 700 deaths occurred in St. James Parish during the seventeen weeks that the cholera raged. The death rate was 220 per 10,000 in the parish, which contained a population in 1851 of 36,406. In the districts adjoining St. James Parish the death rate varied from 9 to 33 per 10,000.

Snow made a careful epidemiological study of the outbreak and compiled the data shown in Table 3-1.

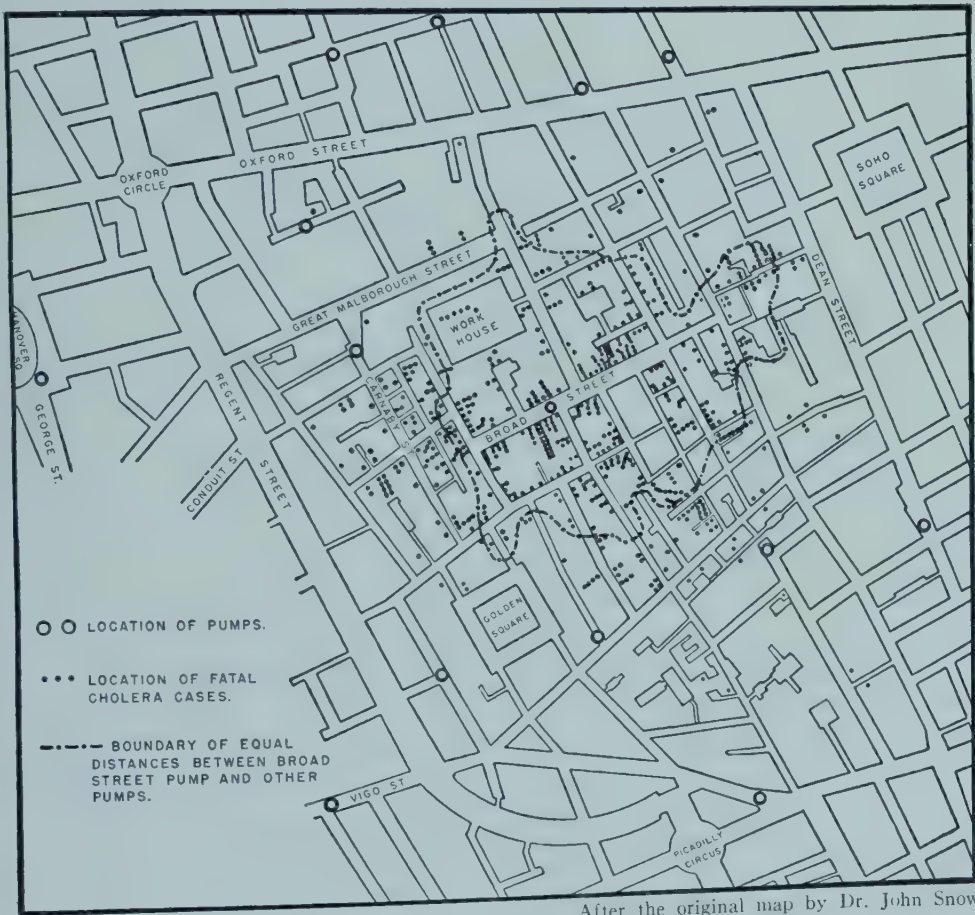
Table 3-1. The Broad Street (London) well and deaths from Asiatic cholera near it in 1854

Date	Number of Fatal Attacks	Deaths	Date	Number of Fatal Attacks	Deaths
Aug. 19 . . . . .	1	1	Sept. 11 . . . . .	5	15
Aug. 20 . . . . .	1	0	Sept. 12 . . . . .	1	6
Aug. 21 . . . . .	1	2	Sept. 13 . . . . .	3	13
Aug. 22 . . . . .	0	0	Sept. 14 . . . . .	0	6
Aug. 23 . . . . .	1	0	Sept. 15 . . . . .	1	8
Aug. 24 . . . . .	1	2	Sept. 16 . . . . .	4	6
Aug. 25 . . . . .	0	0	Sept. 17 . . . . .	2	5
Aug. 26 . . . . .	1	0	Sept. 18 . . . . .	3	2
Aug. 27 . . . . .	1	1	Sept. 19 . . . . .	0	3
Aug. 28 . . . . .	1	0	Sept. 20 . . . . .	0	0
Aug. 29 . . . . .	1	1	Sept. 21 . . . . .	2	0
Aug. 30 . . . . .	8	2	Sept. 22 . . . . .	1	2
Aug. 31 . . . . .	56	3	Sept. 23 . . . . .	1	3
Sept. 1 . . . . .	143	70	Sept. 24 . . . . .	1	0
Sept. 2 . . . . .	116	127	Sept. 25 . . . . .	1	0
Sept. 3 . . . . .	54	76	Sept. 26 . . . . .	1	2
Sept. 4 . . . . .	46	71	Sept. 27 . . . . .	1	0
Sept. 5 . . . . .	36	45	Sept. 28 . . . . .	0	2
Sept. 6 . . . . .	20	37	Sept. 29 . . . . .	0	0
Sept. 7 . . . . .	28	32	Sept. 30 . . . . .	0	0
Sept. 8 . . . . .	12	30	Date unknown . . . . .	45	0
Sept. 9 . . . . .	11	24			
Sept. 10 . . . . .	5	18	Total . . . . .	616	616

It will be seen that the disease broke out with special intensity upon August 30 and declined noticeably after September 10. The pump had been removed on September 8. Snow's inquiry showed that most of the victims had preferred or had access to the water of the Broad Street well, and in a few cases only was it impossible to trace any connection with that source. Thus, with regard to 73 deaths

occurring in the locality of the pump and studied especially with reference to this point, it was found that there were 61 instances in which the deceased persons used to drink the water from the pump in Broad Street, either constantly or occasionally. In six instances no information could be obtained, and in six cases it was stated that the deceased persons did not drink the pump water before their illness.

On the other hand, Snow discovered that, while a workhouse (almshouse) in Poland Street was three-fourths surrounded by houses in which cholera deaths occurred, out of 535 inmates of the workhouse only five cholera deaths occurred. The workhouse, however, had a well of its own in addition to the city supply, and never sent for water to the Broad Street pump. If the cholera mortality in the workhouse had been equal to that in its immediate vicinity it should have had 50 deaths.



After the original map by Dr. John Snow.

Fig. 3-1. Asiatic cholera and the Broad Street pump, London, 1854.

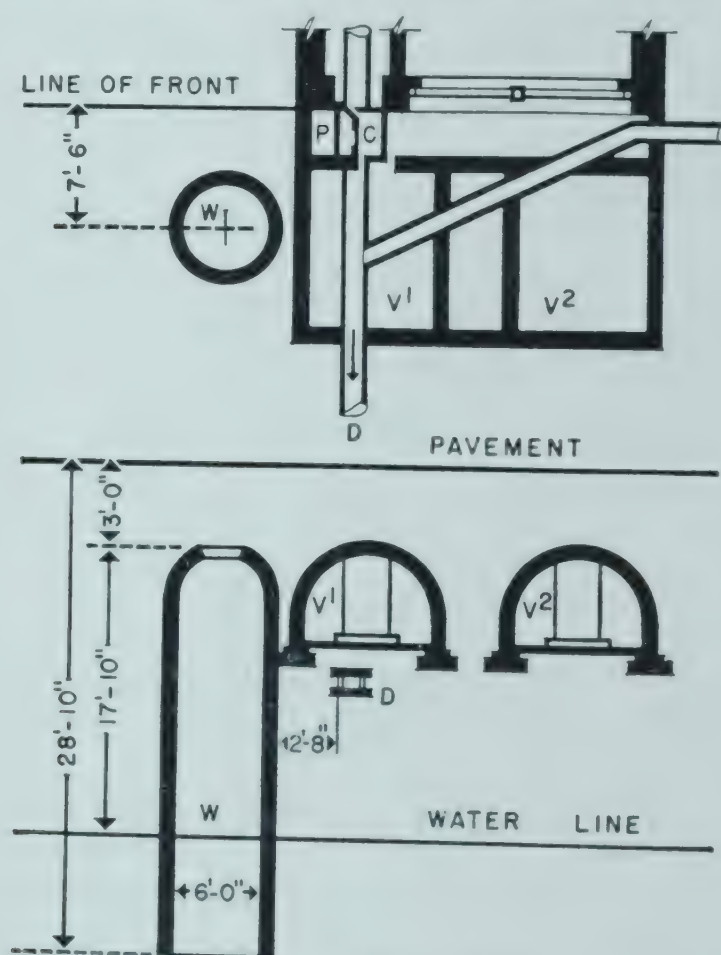
A brewery in Broad Street employing 70 workmen was entirely exempt, but, having a well of its own, and allowances of malt liquor having been customarily made to the employees, it appeared likely that the proprietor was right in his belief that resort was never had to the Broad Street well.

It was quite otherwise in a carriage factory at No. 38 Broad Street, where about 200 workpeople were employed, two tubs of drinking water having been kept on the



premises and always filled from the Broad Street well. Among these employees, 18 died of cholera. Similar facts were elicited for other factories on the same street, all tending to show that in general those who drank the water from the Broad Street well suffered either from cholera or diarrhea, while those who did not drink that water escaped. The whole chain of evidence was made absolutely conclusive by several remarkable and striking cases in Snow's report like the following:

"A gentleman in delicate health was sent for from Brighton to see his brother at No. 6 Poland Street who was attacked with cholera and died in 12 hours, on the first of September. The gentleman arrived after his brother's death, and did not see the body. He only stayed about 20 minutes in the house, where he took a hasty and scanty luncheon of rump steak, taking with it a small tumbler of cold brandy and water, the water being from the Broad Street pump. He went to Pentonville, and was attacked with cholera on the evening of the following day, and died the next evening.



After John York's original drawings

Fig. 3-2. Asiatic cholera and the Broad Street well, London, 1854.

*W*, well; *D*, main drain of house no. 40; *v*<sup>1</sup> and *v*<sup>2</sup>, cellars under street; *C*, cesspool; *P*, privy

"The deaths of Mrs. E. and her niece, who drank the water from Broad Street at the West End, Hampstead, deserve especially to be noticed. I was informed by Mrs. E.'s son that his mother had not been in the neighborhood of Broad Street for many months. A cart went from Broad Street to West End every day, and it was

the custom to take out a large bottle of the water from the pump in Broad Street, she preferred it. The water was taken out on Thursday, the 31st of August, and she drank of it in the evening and also on Friday. She was seized with cholera on the evening of the latter day, and died on Saturday. A niece who was on a visit to this lady also drank of the water. She returned to her residence, a high and healthy part of Islington, was attacked with cholera, and died also. There was no cholera at this time, either at West End or in the neighborhood where the niece died. Besides these two persons only one servant partook of the water at West End, Hampstead, and she did not suffer, or, at least, not severely. She had diarrhea."

John York, Secretary and Surveyor of the Cholera Inquiry Committee, was instructed to survey the locality and examine the well, cesspool, and drains at No. 40 Broad Street (Sedgwick, 1902). His report revealed the following condition of affairs: The well was circular in section, 28 feet 10 inches deep, 6 feet in diameter, lined with brick, and when examined (April, 1855) contained 7 feet 6 inches of water. It was arched in at the top, dome fashion, and tightly closed at a level 3 feet 6 inches below the street by a cover occupying the crest of the dome. The bottom of the main drain of the house from No. 40 Broad Street lay 9 feet 2 inches above the water level, and one of its sides was distant from the brick lining of the well only 1 foot 8 inches. This was an old-fashioned drain 12 inches wide, with brick sides; the top and bottom were made with old stone. It had a small fall to the main sewer. The mortar joints of the old stone bottom were found to be perished, as was also the pointing of the brick sides, which had brought the brickwork into the condition of a sieve, through which the house drainage must have percolated for a considerable period. Snow found the cesspool intended for a trap, but misconstructed, and upon and over a part of the cesspool a common privy, without water supply, for the use of the house had been erected. The brickwork of the cesspool was found to be in the same decayed condition as the drain. Snow states that, "from the charged condition of the cesspool, the defective state of its brickwork, and also that of the drain, no doubt remains upon my mind that constant percolation, and for a considerable period, had been conveying fluid matter from the drains into the well. A washed appearance of the ground and gravel flow corroborated this assumption. The ground between the cesspool and the well was black, saturated, and in a swampy condition, clearly demonstrating the fact." This evidence, while only circumstantial, is sufficient to connect the cesspool with the well, and can leave no doubt in the minds of those who study this interesting and instructive instance that the water became infected with cholera germs through this channel. It should be remembered that this outbreak occurred before the days of bacteriology, so that direct proof is not at hand. As far as could be determined, the infection of the well came from an unrecognized case of cholera in the house at No. 40 Broad Street. There were 4 severer cases of cholera subsequently in the same house.

The Cholera Epidemic in Hamburg in 1892. This epidemic stands out clearly, not only as the most devastating of its kind, but as one of the most instructive. The relation between the infected water and the disease was conclusively proved, and the value of slow sand filtration placed upon a strong foundation. The conditions of the epidemic were equal to those of a well-controlled laboratory experiment, and the bacteriological and epidemiological evidence corroborated each other in every essential particular.



From August 17 to October 23, 1892, a little over two months, there were nearly 17,000 cases of cholera in Hamburg (population 640,000), with 8,065 deaths. On one day during the height of the epidemic over 1,000 new cases occurred. This was a pandemic year for cholera in the sense that it showed a remarkable tendency to spread to all parts of the world. It traveled from the valley of the Ganges through Persia, to Russia, Germany, Austria, France, Belgium, Holland, and the disease was brought to our own doors and several cases occurred in New York City.

The epidemic involved Hamburg, Altona and Wandsbeck. Hamburg and Altona are adjacent but separate cities. Hamburg, being an old Hanseatic city, had its own government. Altona, however, is in Prussia. Wandsbeck (population 20,000) is a nearby suburban town. Each of these three places at the time of the epidemic had a separate water system. Wandsbeck drank from an independent supply taken from



Fig. 3-3. Water Supply of Hamburg.

Hamburg received its water supply from the Elbe River (unfiltered) at G. The sewerage of Hamburg entered the Elbe at ABC. Altona received its water supply from the Elbe at D, about 8 miles below ABC. The sand filters which purified this water were located at Blankenese. Wandsbeck had an independent water supply from a small lake.

a small lake. Hamburg and Altona were both furnished with water from the Elbe River, which is a grossly polluted stream. Both the cities of Hamburg and Altona rest upon the bank of the Elbe River, but Altona is below or downstream. At the time of the epidemic the intake for the water supply of each city was directly at the river front, and the sewers of the city emptied into the river at various points along the same river fronts. It will, therefore, be seen that Altona had Elbe River water plus Hamburg's sewage. Altona, however, filtered this water by the slow sand process; Hamburg furnished its citizens with the raw, unfiltered Elbe River water. This water was first pumped to a single reservoir, which at one time held approximately a day's supply, but had long become inadequate. It will, therefore, be seen that these three cities, with a homogeneous population, with the same climate, the same low-lying site, and all other conditions similar, differed only in their water supplies.

Relatively few cases occurred in Altona, and most of these were on the boundary, where the people probably had access to Hamburg's raw, unfiltered Elbe River water. In Koch's own words, "cholera in Hamburg went right up to the boundary of Altona and there stopped. In one street, which for a long way forms the boundary, there was cholera on the Hamburg side, whereas the Altona side was free from it."

During the epidemic the deaths in the several cities were as shown in Table 3-2.

Table 3-2. Deaths and death rates from cholera in three cities in 1892

City	Population	Deaths	Deaths per 10,000 Inhabitants
Hamburg	640,400	8,605	134.4
Altona	143,000	328	23.0
Wandsbeck	20,000	43	22.0

Further evidence consisted in the fact that at one point close to and on the Hamburg side of the boundary line between Hamburg and Altona was a large yard known as the Hamburger Platz. It contained two rows of large and lofty dwellings containing 72 separate tenements and some 400 people belonging almost wholly to those classes who suffered most from cholera elsewhere in Hamburg. While cholera prevailed all around, no single case occurred among the many residents of this court during the whole epidemic. Koch found that, owing to local difficulties, water from the Hamburg mains could not easily be obtained for the dwellings in question, and hence a supply had been obtained from one of the Altona mains in an adjacent street. This was the only part of Hamburg that received Altona water, and it was also the only spot in Hamburg in which was aggregated a population of the class in question which escaped the cholera.

The source of the epidemic was traced to Russian immigrants crowded in barracks on one of the wharves pending their embarkation for the United States, and at the time of the outbreak there were on an average about 1,000 of these people on hand all the time. Many of them came from districts in Russia which had been, and were then, suffering severely from cholera, and all were well supplied with dirty clothing and blankets, some of which they washed while they were being detained. It is believed that among those that had arrived there must have been some mild cases of the disease, or at least some convalescents and carriers. All of the sewage matters of every description from these people were discharged directly into the river at the wharf. After the Elbe River once became seeded with the cholera vibrio the people in Hamburg who drank this infected water took the disease, and their discharges, returning to the river, added fuel to the flames. A vicious circle was thus set up, so that the infection became exceedingly concentrated and intense, and as the circle was a short one the time interval was correspondingly brief and the virulence unusually severe.

The Hamburg outbreak will ever remain classic on account of the clearness of the circumstances and the fact that there is no missing link in the chain of evidence as the specific organism was readily isolated from the Elbe River water. The conditions proved the effectiveness of filtering out cholera, and gave a greater impetus



to slow sand filtration, thus illustrating the saying that an epidemic may save more lives than it costs.

**OTHER MODES OF TRANSFERENCE.** In addition to the violent outbreaks, cholera occurs in nests or smolders like endemic typhoid. It is difficult to trace the connection between cases in endemic areas. Thus, a careful study of the cholera situation in Manila disclosed the fact that isolated cases would crop up at widely different points without any evident connection between them. Cholera carriers were suspected and later demonstrated. At irregular intervals of several years the disease would gather force, and cases multiply, until it assumed epidemic proportions, entirely independent, it is believed, of the water supply. The way cholera was dragged across our continent by the "forty-niners," and its occurrence among the Mecca pilgrims, are instances of its spread largely independent of infected water.

**CONTACT INFECTION.** Contact infection in cholera must not be underestimated. Persons frequently become infected through handling the dejecta or through freshly infected fomites, such as soiled linen. Direct transmission from person to person was formerly seen among physicians and nurses. In congested quarters, where many persons live under uncleanly conditions, contact infection plays an important part. The same thing may be seen on board vessels, in which case the disease may be confined to the firemen, stewards or some other limited group who are required to live in close contact with each other. Epidemic outbreaks due to contact infection have been recorded.

*Milk* may be contaminated, but is rarely a medium of infection because raw milk is not a common article of diet among the peoples living in countries where cholera prevails. Green vegetables and fruit that have been washed in an infected water may convey the disease.

**FLIES, ETC.** It has been shown that the cholera vibrios may live in the intestines of flies for at least three days, and these and other insects may also spread the infection mechanically. The cholera vibrio is a frail organism and dies rapidly when dried or exposed to light and other injurious influences. Infection through the air is, therefore, not to be dreaded. Fomites, such as bed and body linen or other objects, including spoons, dishes, toys, etc., contaminated with the discharges, can be regarded as possible sources of infection. There is, however, a special limitation in this case, owing to the fact that this organism is so readily destroyed by desiccation and crowded out by saprophytic micro-organisms. Thus, as a rule, only fresh dejecta and freshly contaminated objects are possible hazards.

**Immunity and Prophylactic Inoculation.** An attack of cholera does not necessarily confer protection against a subsequent attack. Nevertheless, second attacks within a period of a few years are uncommon. Attempts to immunize man with cholera vaccines were made by Ferran in Spain in 1884, and Haffkine in 1895. The latter used live avirulent cultures followed by virulent cultures. Reactions were so severe that the procedure soon fell into disfavor. Kolle showed that killed cultures were antigenically efficacious.

The vaccine approved by the Allied Armed Forces during World War II consisted of an 18-hour growth on infusion agar emulsified in sterile salt solution standardized to contain 8 thousand million vibrios per milliliter and killed by adding phenol to a final concentration of 0.5 per cent. The final product contains 4 thousand million Inaba and 4 thousand million Ogawa vibrios per milliliter in 0.5 per cent

phenol saline. On storage, autolysis may occur so that the vaccine becomes almost water clear; this does not interfere with its activity. It is given subcutaneously in two doses, the first 0.5 ml., the second 1 ml. after a ten-day interval. Reactions to these injections are analogous in severity to those sustained after inoculation with typhoid vaccine. The immunity conferred is thought to last less than a year so that a stimulating dose of 1 ml. should be given subcutaneously at six-month intervals to maintain protection continuously.

There is an extensive literature dealing with the protective value of various preparations of cholera vaccine in human populations under conditions of natural exposure. In general, the consensus of opinion has been that it is of value, although this judgment is rendered uncertain by lack of comparability of the inoculated and uninoculated groups. In a recent study made in India (Adishesan and others, 1947), the carefully analyzed evidence indicated that a single dose of the vaccine used reduced the risk of a clinical attack, but did not change the case fatality from cholera. The attack rate in the uninoculated population was found to be two and one-half times greater than that in the inoculated population under conditions of comparable exposure.

**International Quarantine.** International cooperation in public health and sanitary matters took its origin in the efforts to prevent spread of epidemics of cholera and plague from the East to the European countries. The practice of maritime quarantine has become increasingly effective during the past century as one country after another has organized a system of inspection, detention and disinfection of ships, aircraft and other common carriers at the port of arrival. Cholera is particularly amenable to quarantine measures. It has a short incubation period. Passengers coming from an infected local area or who have been in contact with a suspected case may be placed under surveillance for a period of not more than five days. The onset of the disease is abrupt and the clinical course is short, ending in recovery or death within a few days. The diagnosis can be accurately and rapidly confirmed by laboratory procedures and the carrier state is relatively short. Detention and quarantine of convalescents and carriers is ordinarily not prolonged. International Sanitary Regulations now in force are those adopted by WHO (1951). The possession of a valid certificate of vaccination against cholera is taken into consideration by the health authority in applying measures provided for in the regulations.

**Community Control.** In those areas of the world, particularly southeast Asia where the disease still occurs, principal reliance is placed upon mass immunization with cholera vaccines to control epidemics. Prevention of epidemics and reduction of the endemic prevalence of the disease can be accomplished only by improving the conditions of living in regard to water supply, fecal disposal and home and personal hygiene. Only a little improvement in the level of sanitation may be required to have a decided effect.

Scrupulous cleanliness on the part of the person and his surroundings is required. Those who handle cholera patients, their dejecta, or infected articles must carefully disinfect their hands each time and should under no circumstances eat or drink anything in the sick room. During cholera times all water and food of every description should be boiled or thoroughly cooked just before it is eaten. Great care must be exercised that the water or food does not become infected after it has been boiled or cooked.



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## TYPHOID FEVER

Typhoid fever was confused for centuries with other continued fevers, such as recurrent fever, septic infections and typhus fever. The first full description of what was probably typhoid fever was written by Thomas Willis, an English physician, who, in 1643, described an epidemic that occurred in Parliamentary troops. Bretonneau, in 1826, further described the clinical characteristics and called it "dothienenteritis," or abscess of the small intestine, a name it frequently bears in French literature. Louis, the distinguished French clinician, in 1829 gave the name typhoid fever to the malady to distinguish it from typhus fever. In 1836, William Gerhard, of Philadelphia, a pupil of Louis, showed the difference in the lesions between these two fevers, which established typhoid fever as a distinct disease, but it was not until after the middle of the nineteenth century that the disease became widely known under this name in the United States, even to the medical profession.

William Budd, in 1856, pointed out that the disease is transmitted by the patient's excreta. He stated that: "The living human body, therefore, is the soil in which this specific poison breeds and multiplies." The first water-borne outbreaks carefully studied and described was at Lausen, Switzerland, in 1872; the first water-borne outbreak to attract attention in the United States occurred in Plymouth, Pennsylvania, in 1885. In 1875, Murchison traced an epidemic to a contaminated milk supply. Eberth, in 1880, saw the *Bacillus typhosus* in the tissues, and four years later Gaffky grew it in pure culture. Metchnikoff and Besredka, in 1900, finally established the etiological relationship by producing the disease in anthropoid apes with pure cultures. In 1894, Pfeiffer and Kolle first gave small subcutaneous inoculations of dead typhoid bacilli. About the same time, and independently, A. E. Wright began similar inoculations in British soldiers.

Occurrence. Typhoid fever has a world-wide distribution. It is endemic almost everywhere but the level of prevalence varies within wide limits both geographically and in relation to time. With the industrial revolution and the tendency of populations to congregate in cities during the eighteenth and nineteenth centuries, it became

major pestilence in Western Europe and in North America. In many countries is still a public health problem of great importance.

In cities of the United States, death rates of more than 50 per 100,000 were not uncommon and in a few the figure was over a hundred. Prevalence was correspondingly high in the smaller towns and rural districts of the country but during this period somewhat lower than the adjacent urban areas. In the U. S. Registration Area as a whole, typhoid fever was fourth among the communicable diseases as a cause of mortality. In 1900, the death rate was 31.3 per 100,000 population. From that figure it has decreased steadily until in 1948 the rate was 0.2 per 100,000. Recent urban experience is indicated in the accompanying table. It is apparent that in some parts of the country the progress has been more rapid than in others. The downward trend in the cities was paralleled by a downward trend in the rural areas but these lagged behind somewhat so that the disease is now more rural than urban. In some states the higher rates persisted in the smaller towns and villages rather than in the isolated country districts (Leach and Maxcy, 1926). The disease has practically disappeared from large areas in the northern part of the country.

Table 3-3. Total typhoid death rate per hundred thousand of population for ninety-three cities according to geographic divisions

	Population *	Typhoid Deaths			Typhoid Death Rates			
		1945	1944	1943	1941- 1945	1936- 1945	1931- 1940	1935
New England	2,579,152	2	1	6	0.08	0.14	0.39	0.70
Middle Atlantic	13,129,185	30	22	11	0.23	0.17	0.43	0.80
South Atlantic	2,727,985	17	6	8	0.62	0.54	1.14	2.70
East North Central	9,386,378	7	13	24	0.07	0.16	0.53	0.75
East South Central	1,286,747	9	4	8	0.70	0.57	2.54	4.81
West North Central	2,716,484	3	3	3	0.11	0.16	0.60	1.24
West South Central	2,048,692	12	19	17	0.59	0.89	3.09	5.36
Mountain and Pacific	4,186,039	7	5	8	0.17	0.23	0.60	0.88

From J.A.M.A., 131:820, Table 12, 1946.

\* 1940 census figures used.

**Military Experience.** During the wars of the eighteenth and nineteenth centuries, typhoid was ranked with typhus, plague, dysentery, cholera and smallpox as one of the principal causes of mortality and morbidity in military populations. An extreme example of what happened is presented in the report on the origin and spread of typhoid fever in the U. S. military camps during the Spanish-American War of 1898 (Reed and others, 1904). Among 107,973 officers and men in the National encampment, 20,748 had typhoid fever, an attack rate of 19 per cent, and there were 1,580 deaths. Following this report, the importance of military sanitation was realized and gradually adequate provision was made in Army organizations for the application of measures of sanitation in the field.

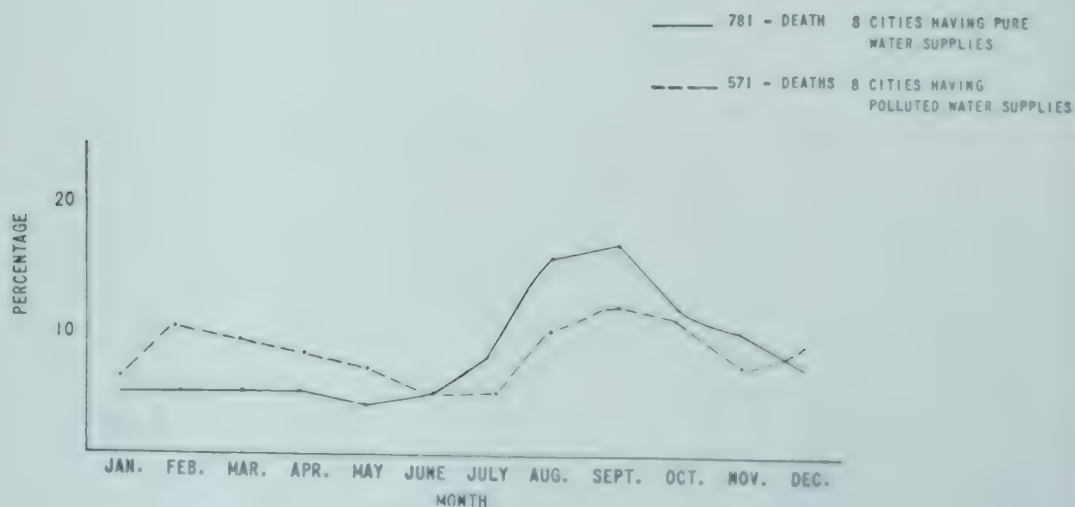
In 1911, the use of prophylactic typhoid vaccination became compulsory; this has continued with some changes in the vaccine preparation. The combined effect of improvement in sanitation in the civil and military population of the United States and of vaccination of Army personnel is indicated in Figure 3-4 (Holt, 1948).





From Holt, R. L., Am. J. Pub. Health, 38:483, 1948

Fig. 3-4. Typhoid fevers, U. S. Army, 1860-1947. Rates per 1,000 per annum.



Adapted from Freeman, A. W., Pub. Health Rep., 32:642, 1917, Table 3.

Fig. 3-5. Seasonal distribution of deaths from typhoid fever in 16 cities in Ohio river basin, 1910-1914.

**Seasonal Distribution.** The seasonal distribution of typhoid fever is indicated in Figure 3-5. In those areas where dissemination by a common water supply is not an important factor, cases occur throughout the year, but are at a minimum during the winter and spring months, rising to a peak in the late summer and early fall. This is generally considered to be the characteristic curve for enteric infections. This distribution is disturbed, however, in those areas where pollution of common water supplies plays a role. Widespread epidemics of water-borne typhoid fever are not unusual in the coldest weather. The explanation for this difference in seasonal distribution is not clear, but there is some reason to believe that typhoid bacilli survive longer in surface water during the colder than during the warmer months of the year.

**Age and Sex.** Where exposure is equal, typhoid fever attacks one sex as readily as the other. It is common experience, however, to find in morbidity and mortality statistics derived from large populations, over long periods of time, that there are more cases among males than females at all ages. This sex difference has been attributed to the fact that the male is apt to be more gregarious and range more widely in his activities, and thus suffers a greater exposure.

Age selection is characteristic and is indicated by the accompanying table showing the mean annual age specific typhoid morbidity rates for New York State, 1928-1932. The disease is less frequently recognized in children under five years and

Table 3-4. Mean annual age-specific typhoid morbidity rates for New York State, exclusive of New York City, 1928-1932

Age Group	Population 1930 Census	Number of Cases	Mean Annual Morbidity Rate per 100,000
0-4	382,871	29	7.6
5-9	428,742	81	18.9
10-19	816,144	161	19.7
20-29	725,476	117	16.1
30-over	2,399,172	209	8.7
TOTAL	4,752,405	597	12.6

From Ramsey, G. H., *Am. J. Hyg.*, 21:665, 1935.

appears to run a somewhat milder course. The highest attack rates are suffered by adolescents and young adults. In older ages the attack rate decreases progressively; this is probably due in part to acquired immunity.

**Period of Incubation.** In epidemics due to transmission by a common vehicle it is frequently possible to fix the time of exposure quite definitely. Since in many individuals the onset of the disease is insidious it is not always equally easy to fix the time of onset. A range of 7 to 21 days encompasses the incubation period for the great majority of cases, the average is about 14 days, and the extremes are 3 to 38 days. It has been suggested that in epidemics transmitted by food, where the dosage is presumably large, the incubation period may be shorter than in water-borne outbreaks where the dosage is presumably small. The validity of this generalization has been questioned.



**The Disease.** The disease is a generalized infection characterized by a continued fever lasting about four weeks. The onset is usually insidious beginning with malaise, anorexia and headache. The temperature rises in a step-like manner to an average of about 104° F, with a pulse rate that tends to be slow in comparison with the height of the fever. During the first week, the patient usually becomes prostrate, nose bleeds are frequent. A diarrhea develops, though constipation is sometimes present, either condition being accompanied by some degree of abdominal tenderness and distension. During the first part of the illness discrete rose-colored spots may be seen scattered over the trunk. The spleen is enlarged. In the more severe cases as time passes the patient may become stuporous or delirious. After the third week the temperature curve begins to show morning remissions and gradually returns to normal by lysis. A leukopenia is present in most cases.

**Pathogenesis.** Typhoid bacilli enter the body through the alimentary tract. They localize and multiply during the incubation period in the lymphoid tissue of the wall of the small intestine and regional lymph nodes. Here micro-organisms may be seen within plasma cells. From this site they enter the blood stream via the lymphatics and thoracic duct. As the defensive mechanism comes into play, endotoxin is produced, causing some of the symptoms of the disease. The micro-organisms localize particularly in the spleen and bone marrow. The gallbladder is invariably infected. Occasionally there is some bronchopneumonia. The involvement of the lymph nodes in the intestines may lead to ulceration and intestinal hemorrhage or perforation. These are serious and often fatal complications. In about 10 per cent of cases after the temperature has returned to normal, a relapse of variable duration occurs. The case fatality rate, based upon clinically recognized and reported cases, has usually been about 10 per cent in the past. Under modern treatment with proper attention to dietary and fluid balance, and with judicious use of antibiotic drugs—aureomycin and chloromycetin—convalescence is shortened. It is not yet clear what effect this has upon the risk of complications, relapse and death.

**Laboratory Diagnosis.** Typhoid bacilli appear in the blood early in the disease; perhaps occasionally during the prodromal symptoms. Kayser obtained positive blood cultures from about 90 per cent of patients during the first week of illness, 65 per cent in the second, 42 per cent in the third and 35 per cent in the fourth. With defervescence the blood cultures become negative but in the event of relapse micro-organisms may reappear in the blood stream. Recovery and identification of *S. typhosa* from blood cultures definitely establishes the diagnosis of typhoid fever.

The bacilli leave the body in feces and urine and occasionally in the sputum and other discharges during the acute illness and for a variable time during convalescence or relapse. The most reliable laboratory test is the isolation of the etiological organism from feces. The frequency with which typhoid organisms can be demonstrated in fecal specimens has been considerably increased by modern bacteriological technique, particularly by employment of selective and enrichment fluid media, such as peptone tetrathionate, and by selective plating media, such as bismuth sulphite agar (Diagnostic Procedures and Reagents, 1950). Repeated examination of specimens is essential, but with proper specimens and bacteriological methods the causative organism can be demonstrated in a great majority of cases at some time during the illness. With defervescence and the establishment of convalescence the frequency of positive stools and urine cultures rapidly decreases.

Formerly a great deal of dependence was placed upon the demonstration of agglutinins in significant titers in the blood serum of the patient, the Widal reaction. It was found that usually, but not always, agglutinins appeared in the blood from between the third and seventh day of the disease, rose at first slowly and then more steeply to a maximum between the sixteenth and twenty-seventh days and then fell slowly so that they were detected for weeks or months after convalescence.

As the antigenic structure of different species of the *Salmonella* group of micro-organisms was elucidated, it became apparent that the interpretation of this agglutination test was not as simple as had been at first thought. It was found that during any febrile illness, agglutinins for *S. typhosa* might appear in the blood as a result of some previous experience with a related organism in the *Salmonella* group or as a result of previous typhoid vaccination. This technical difficulty was partially overcome by Felix and others who showed that a distinction must be made between the development of O (somatic) agglutinins and H (flagellar) agglutinins. It is now routine to test sera against both the formalin-treated or other suspension of *S. typhosa* which has been shown to be satisfactory to demonstrate the flagellar or H type of agglutinins, and the alcohol-treated or other suspension of *S. typhosa* suitable for the demonstration of the granular or O type agglutination. The results of these agglutination tests are to be interpreted by the physician only with a full knowledge of the history of the patient, especially with reference to previous vaccination against typhoid fever. Repetition of the test with standardized reagents should be made in order to secure an index of rise or fall of the agglutinin titer. Only when high titers (O, 1:500 or H, 1:1,000) are reached does the test approach diagnostic value where evidence from repeated attempts to recover the causative micro-organism by culture have failed.

In 1934, Felix and Pitt found that smooth strains of typhoid bacilli differed very widely in regard to their sensitiveness to agglutination by an O antiserum, and that this sensitivity was inversely related to virulence of the strains as judged by the intraperitoneal injection of mice. They showed that this was due to the presence of a special antigenic component which Felix called "Vi" antigen. Human serum may be tested for Vi antibody by employing a living suspension of a pure Vi strain of *S. typhosa*. The presence of Vi antibodies in the human serum is indicative of active infection and useful in the detection of carriers (Felix, 1938).

As soon as the special importance of the so-called Vi antigen of typhoid bacillus was recognized, a number of investigators working independently in different countries established the existence of bacteriophages which were specific for the Vi form of typhoid bacillus. These 'phages attack typhoid strains irrespective of their origin, provided the cultures contain adequate quantity of Vi antigen. By propagating a particular anti-Vi 'phage on typhoid strains isolated from different sources, Craigie and Yen (1938) obtained bacteriophages which had developed a high degree of specificity for the particular strain in which they were grown. When such adapted 'phage preparations were tested against a number of typhoid strains from different localities, it was found that the strains could be divided according to their response to the different 'phage preparations and that strains that were related epidemiologically belonged to the same 'phage type. For use in routine typing a variable number of standard 'phage preparations are recommended. The types are designated by letters of the alphabet and by an added numerical subscript. The types found vary



in different geographic areas (Felix, 1943; Olitski and Shelubsky, 1945; Morris and others, 1945; Crocker, 1947). This procedure has been found of practical value in tracing the sources of small outbreaks of typhoid fever. It can be assumed that cases infected from the same source will be found to have the same Vi phage type of typhoid bacillus. When the epidemiological evidence appears to incriminate a chronic carrier, it can be shown that the carrier is harboring the same Vi phage type as that isolated from the patient.

**Missed Cases and Carriers.** An interesting outbreak of typhoid fever in a population exposed to a contaminated industrial supply was reported by Murphy and others (1944). It occurred in a small mill village with a population of approximately 721. Of these, 701 were kept under observation by the investigators, questioned with regard to the occurrence of clinical symptoms of typhoid and stool specimens obtained from 642. Eighty of these 642 specimens were positive for *S. typhosa*. Thirty-eight were from patients confined to bed for 10 days or more, and 20 from one to nine days. Eleven of those who had positive stools were ambulatory at all times and in 11 more there was no history of illness. Two of the latter became chronic carriers. Little more than one half of the 69 cases with symptoms were treated by physicians; several others were discovered through the efforts of the health authorities; 23 additional cases, as well as 11 asymptomatic infections, were discovered through a house-to-house canvass. This illustrates the fact that where careful studies are made during a typhoid outbreak the organism is more widely distributed in the population than would be indicated from the occurrence of cases which are diagnosed and reported by physicians.

At least 50 per cent of cases continue to discharge typhoid bacilli in their feces for three weeks after the onset of the disease, and about 5 per cent are still discharging the organisms after 11 to 13 weeks. At the end of five months, the figure has decreased to about 3 per cent. These are known as *convalescent carriers*. A *chronic carrier* is a person who has not suffered from typhoid fever within the previous 12 months and who discharges typhoid bacilli—in other words, individuals who may or may not have had a clinically recognized attack of typhoid fever but who continue to excrete the organism over a period of at least one year. Those who harbor the organism without having had a clinically recognized attack are sometimes called *healthy carriers*.

The frequency of the carrier state in relation to age and sex is indicated by the accompanying table. These data are in accord with general experience in this regard. Older persons are more likely to become carriers than children; there are more females than males; the highest frequency is found in females aged 40-49. These facts are helpful in epidemiological investigations directed toward finding a carrier.

With the data available from the experience of New York State and making certain reasonable assumptions, Ames and Robbins estimated that as of January 1, 1940, there were, in a total population of 5,952,000, approximately 2,490 carriers, or a carrier prevalence rate of 41.8 per 100,000. At this time there were under supervision of the State Department of Health only 419 known carriers, or about 16 per cent of the estimated total number. The carrier prevalence rate varies in different populations according to the past and current level of prevalence of typhoid.

Most of the outbreaks of typhoid fever traced to carriers turn out to be due to individuals who discharge typhoid bacilli in the feces rather than in the urine. Some

carriers are more dangerous than others. This is due partly to personal habits, partly to the opportunity to infect food and drink, partly to virulence and number of organisms discharged. Further, carriers are intermittent or irregular in the elimination of typhoid bacilli. Typhoid carriers in dairies have been responsible for many outbreaks; a carrier employed as a cook, waiter or a nurse in a dairy is a special menace. The amount of harm which a single individual can cause is amazing.

Table 3-5. Typhoid cases and resulting chronic carriers by age and sex in New York State, exclusive of New York City and state institutions, 1930-1939

Age at Time of Typhoid	Number of Cases		Number of Carriers		Per Cent of Cases Resulting in Carriers		
	M	F	M	F	M	F	Both Sexes
Under 10	347	281	2	—	0.6	—	0.3
10-19	491	411	2	1	0.4	0.2	0.3
20-29	341	238	7	5	2.1	2.1	2.1
30-39	216	193	6	12	2.8	6.2	4.4
40-49	173	122	6	20	3.5	16.4	8.8
50-59	110	78	10	9	9.1	11.5	10.1
60 and over	65	64	4	6	6.2	9.4	7.8
TOTAL	1,743	1,387	37	53	2.1	3.8	2.9

From Ames, W. R., and Robbins, M., Am. J. Pub. Health, 33:221, 1943.

The story of *Typhoid Mary* was the first of its kind to be reported in America, and it has become a classic. Mary Mallon was a cook in a family for three years, and in 1901 she developed typhoid fever. About the same time a visitor to the family had the disease. One month later the laundress in this family was taken ill.

In 1902, Mary obtained a new place, and two weeks after her arrival the laundress was taken ill with typhoid fever. In a week, a second case developed, and soon seven members of the household were sick.

In 1904, the cook went to a home on Long Island. There were four in the family, besides seven servants. Within three weeks after her arrival, four servants were attacked.

In 1906, Mary went to another family, and six of the 11 members of this family were attacked with typhoid between August 27 and September 3. At this time, the cook was first suspected. She entered another family on September 21, and on October 5 the laundress developed typhoid fever.

In 1907, she entered a home in New York City and two months after her arrival two cases developed, one of which proved fatal. During these five years, "Typhoid Mary" is known to have been the cause of 26 cases of typhoid fever.

She was virtually imprisoned by the New York Department of Health in a hospital from March 19, 1907. Cultures taken every few days showed bacilli on and off for three years. Sometimes the stools contained enormous numbers of typhoid bacilli, and again for days none could be found.

"Typhoid Mary" then escaped from observation until 1914. In October of that



year, she was engaged as cook in the Sloane Hospital for Women in New York. In January and February of 1915, an outbreak of typhoid occurred, principally among the doctors, nurses and help of the institution, involving 25 cases. The cook was suspected, but she left the premises on a few hours' leave, and did not return or leave her address. She was, however, located by the Health Department under an assumed name, and an investigation established her identity as the famous "Typhoid Mary."

A subsequent study of her career showed that she had infected still other individuals beyond those already mentioned, and that she may have given rise to the well-known water-borne outbreak of typhoid in Ithaca, New York, in 1903, involving over 1,300 cases. The fact is that a person by the name of Mary Mallon had been employed as a cook in the vicinity of the place where the first case appeared, and from which contamination of the water supply occurred.

**OTHER EXAMPLES.** Sawyer (1915) reported a very instructive history of a typhoid carrier (H. O.) responsible for several outbreaks. The carrier was carefully studied over a period of several years, during which time he infected 30 persons, five of whom died. Frequent examinations of feces of this carrier gave negative results for four months after he had been treated with autogenous typhoid vaccines; nevertheless, he infected three persons when subsequently released from quarantine on parole. The removal of the gallbladder failed to cure H. O., for typhoid bacilli were found in the feces several times after the operation. It is particularly noteworthy that 41 successive examinations of feces during a period of 14 months all proved negative, yet the typhoid bacillus was finally isolated from the stomach contents containing bile. This carrier, on account of the virulence of the organism, or careless personal habits, is unusually dangerous and represents a class that should be controlled by quarantine or close supervision.

Another instructive outbreak occurred in Hanford, California, in which 93 cases of typhoid fever resulted from a large pan of spaghetti prepared by a carrier and served at a public dinner (Sawyer, 1914). This dish was baked after it had been infected, but this baking was shown by laboratory experiments to have incubated the bacteria in the center of the mass.

**Control of Carriers.** As typhoid decreases to a low level of prevalence with improved sanitation, discovery and supervision of carriers becomes increasingly important. A typhoid carrier register is gradually accumulated through information gained from various sources. The principal methods of discovery are through follow-up of current cases during convalescence with periodic stool and urine examinations, and through epidemiological investigations tracing the sources of small groups of sporadic cases, delimiting endemic foci. Rarely are carriers discovered by routine examination of stool specimens of persons working as food-handlers. Occasionally one is picked up by the routine examination of bile from gallbladders removed in cholecystectomy. As they are discovered, the carriers are placed under supervision either voluntarily or by legal compulsion. Thereafter, they should be visited twice a year by the appropriate health official. With proper care and cleanliness they may present little danger to their fellowmen. However, this requires proper instruction and intelligent cooperation. Each carrier should be instructed with regard to personal hygiene and prohibited from preparing food for any person except members of his own household who have been vaccinated against

typhoid fever within two years. It is particularly important that all convalescent and chronic carriers be prohibited by law from preparing food for the public, including the handling of milk and milk products on farms or in milk plants (Committee on Administrative Practice, 1949).

It is unusual to find an exception to the rule that chronic carriers will be carriers for the rest of their lives, unless the focus of infection be removed by operation. No drug or antibiotic (including aureomycin and chloromycetin) has yet been found which will cure the chronic carrier state. Only a few spontaneous cures without operation have been recorded.

Removal of the gallbladder for the cure of chronic typhoid carriers should be advised only after careful consideration of the physical condition and age (under 60 years) of the carrier and should not be advised unless preliminary duodenal specimens show the presence of typhoid bacilli in the bile. A typhoid carrier who has had his gallbladder removed will often continue to excrete typhoid bacilli for several days, and in some instances for from one to six months after the operation. When the stool specimens become negative, monthly specimens should be obtained until 12 months have elapsed since the first negative specimen. Final release should depend upon the failure to find typhoid bacilli in the bile obtained by duodenal tube, and examination of the next two stool specimens after giving magnesium sulphate through the duodenal tube. In the State of Massachusetts (Bigelow and Anderson, 1933), this operation is done at the public health expense; this is cheaper and more effective than subsidies. Senftner and Coughlin (1933), reviewing the experience of New York State, found that in 68 persons operated on, excluding those with gallbladder symptoms, the mortality was 3.7 per cent. Of those who survived the operation, 68 per cent were apparently cured of the carrier condition.

**Resistance of the Bacillus.** The typhoid bacillus has no spore. It is, therefore, comparatively easy to destroy. The only difficulty presenting itself is getting at the bacillus when imbedded in fecal masses. When dry, most typhoid bacilli die in a few hours; occasionally a few survive for months. The fact that most typhoid bacilli are killed by drying renders infection through dust unlikely.

In a moist medium, such as water, milk, or urine, typhoid bacilli are killed at 60° C in 20 minutes. They are not destroyed by freezing.

In their resistance to germicides typhoid bacilli behave like the average nonspore-bearing bacilli. Thus, bichloride of mercury, 1:1,000; phenol 2.5 per cent; formaldehyde solution, 10 per cent, are effective upon the naked germs. In order to kill the typhoid bacilli in feces, special precautions, longer exposures or stronger solutions are necessary (see page 204).

The viability of typhoid bacilli in feces is very variable, depending on the composition of the feces and the varieties of other bacteria present. Sometimes the typhoid bacilli in feces perish in a few hours, often in a day; under certain circumstances they may live for much longer periods. Levy and Kayser found that they may remain alive in feces for five months in the winter. The life of the organism in privies and in water is usually comparatively short. In nature they seldom, if ever, live in water beyond seven days, and are often dead in 48 hours. They probably live longer in clean water than in contaminated water; in cold water than warm water. In the outer world, antibiosis plays an important part, also the presence of deleterious chemicals, temperature, sunlight, and other factors known to be injurious to



spore-free bacteria. As a rule, the typhoid bacillus does not survive long in the soil under the usual conditions.

The typhoid bacillus may live 12 days in crude sewage (Firth); 14 days in a septic tank (Pickard); four months in butter (Balley and Field); five days in home-made cheese (Heim); 12 days in pot cheese (Lemke); 39 days in ice cream (Mitchell). These are maxima. It is destroyed in 24 hours in milk, buttermilk, whey or butter having an acidity of 0.3 to 0.4 per cent. Krumwiede and Noble found that with a moderate contamination, typhoid bacilli are killed in sour cream in approximately four days.

The typhoid bacillus is an obligate human parasite. It lives and grows principally in the human body. It has a tendency to die in water, air, soil, upon fomites, or in nature generally in a comparatively short time except under special circumstances as in the case of milk, in which it grows well. The ultimate sources of all typhoid infections are patients, missed cases and carriers.

**Transmission.** Transmission may be rather direct by contaminated fingers to food, i.e., by "contact," or indirect through water, milk, milk products, oysters or other foods, i.e., by a common vehicle.

**Water-Borne Typhoid.** Water-borne typhoid is a common occurrence. Not long ago it was regarded as the sole or usual mode of spread; now we know that this was a mistake. Most fecal matter ultimately finds its way to water; most water courses draining inhabited regions are contaminated with human feces. Surface water is, therefore, apt to contain typhoid bacilli. The fact that there may be no clinical case of typhoid fever in the drainage area is no guarantee that the water may not be infected—in view of the prevalence of missed cases and bacillus carriers.

Fortunately, typhoid bacilli do not grow and multiply in water under natural conditions. They usually die in a few days, and rarely persist longer than seven days. They succumb more quickly in some waters than others, more quickly in summer than winter. Ruediger (1911) has shown that typhoid bacilli disappear much more rapidly from polluted water during the summer months than during the winter months when the river is protected with a covering of ice and snow.

Water plays a large but diminishing role in the spread of typhoid fever, on account of filtration, chlorination and sanitary control of water supplies. The great water-borne epidemics have overshadowed the other modes of communication. Whipple, in 1908, estimated that 35 per cent of the typhoid in this country was water-borne; now it occurs only occasionally.

In the vast majority of cases, water-borne typhoid is contracted from a surface supply; that is, a river, small stream, pond or lake. Ground water becomes a source of danger only under special conditions, especially in limestone regions. Bathing in polluted water is an occasional cause.

#### HISTORICAL EPIDEMICS DUE TO POLLUTED WATER SUPPLIES

**The Typhoid Epidemic at Lausen, Switzerland.** The epidemic of typhoid fever which occurred in Lausen, Switzerland, in 1872, was the first to attract general attention, "and, because of certain peculiar conditions connected with it, and especially because of its influence upon the theory and practice of the purification of water by filtration, it deserves the most careful consideration by all students of sanitation." It is also interesting because of the remoteness and unusual method by

which the infection reached the water supply. The following account of this epidemic is from the description by Sedgwick, quoting Hagler's report:

The epidemic occurred in the little village of Lausen in the canton of Basel in Switzerland in August, 1872. Lausen was a well-kept village of 90 houses and 780 inhabitants, and had never, so far as known, suffered from a typhoid epidemic. For many years it had not had even a single case of typhoid fever, and it had escaped cholera even when the surrounding country suffered from it. Suddenly, in August, 1872, an outbreak of typhoid fever occurred, affecting a large part of the entire population.

A short distance south of Lausen is a little valley, the Fürlethal, separated from Lausen by a hill, the Stockhalden, and in this valley, on June 19, upon an isolated farm, a peasant, who had recently been away from home, fell ill with a severe case of typhoid fever, which he had apparently contracted during his absence. In the next two months there occurred three other cases in the neighborhood—a girl, and the wife and son of the peasant.

No one in Lausen knew anything of these cases in the remote and lonely valley, when suddenly, on August 7, 10 cases of typhoid fever appeared in Lausen, and by the end of nine days 57 cases. The number rose in the first four weeks to more than 100, and by the end of the epidemic in October to about 130, or 17 per cent of the population. Besides these, 14 children who had spent their summer vacation in Lausen fell ill with the same disease in Basel. The fever was distributed quite evenly throughout the town, with the exception of certain houses which derived their water from their own wells and not from the public water supply. Attention was thus fixed upon the latter, which was obtained from a well at the foot of the Stockhalden hill on the Lausen side. The well was walled up, covered, and apparently protected, and from it the water was conducted to the village, where it was distributed by several public fountains. Only six houses used their own wells, and in these six there was not a single case of typhoid fever, while in almost all the other houses of the village, which depended upon the public water supply, cases of the disease existed. Suspicion was thus directed to the water supply as the source of the typhoid, largely because no other source could well be imagined.

There had long been a belief that the Lausen well or spring was fed by and had a subterranean connection with a brook (the Fürler brook) in the neighboring Fürler valley; and since this brook ran near the peasant's house and was known to have been freely polluted by the excreta of the typhoid fever patients, absolute proofs of the connection between the well of Lausen and the Fürler brook could not fail to be highly suggestive and important. Fortunately, such proofs were not far to seek. Some 10 years before observations had been made which had shown an intimate connection between the brook and the well. At that time, without any known reason, there had suddenly appeared near the brook in the Fürler valley below the hamlet a hole about eight feet deep and three feet in diameter, at the bottom of which a considerable quantity of clear water was flowing. As an experiment the water of the little Fürler brook was at that time turned into this hole, with the result that it had all flowed away underground and disappeared, and an hour or two later the public fountains at Lausen, which, on account of the dry weather prevailing at the time, were not running, had begun flowing abundantly. The water from them, which was at first turbid, later became clear; and it had continued to



flow freely until the Fűrler brook was returned to its original bed and the hole had been filled up. But every year afterward, whenever the meadows below the site of the hole were irrigated, or overflowed, by the waters of the brook, the Lausen fountains soon began to flow more freely. In the epidemic year (1872) the meadows had been overflowed as usual from the middle to the end of July, which was the very time when the brook had been infected by the excrements of the typhoid patients. The water supply of Lausen had increased as usual, had been turbid at the beginning, and had had a disagreeable taste. And about three weeks after the beginning of the irrigation of the Fűrler meadows typhoid fever had broken out, suddenly and violently, in Lausen.

In order to make matters more certain, if possible, the following experiments were made, but unfortunately not until the end of August when the water of the Lausen supply had again become clear. The hole which had appeared 10 years earlier, and had afterward been filled up, was reopened, and the little brook was once more led into it; three hours later the Lausen fountains were yielding double their usual volume. A quantity of brine containing about 18 hundred pounds of common salt was now poured into the brook as it entered the hole, whereupon there appeared very soon in the Lausen water first a small, later a considerable, and finally a very strong reaction for chloride, while the total solids increased to an amount three times as great as before the brine was added. In another experiment 5,000 pounds of flour (Mehl), finely ground, were likewise added to the brook as it disappeared in the hole; but this time there was no increase of the total solids, nor were any starch grains detected in the Lausen water.

It was naturally concluded from these experiments that while the water of the brook undoubtedly passed through to Lausen and carried with it salts in solution, it nevertheless underwent a filtration which forbade the passage of suspended matters as large as starch grains. Hagler, from whose report the foregoing facts are taken, was careful, however, to state that "it is not denied that small organized particles, such as typhoid fever germs, may nevertheless have been able to find a passage." As a matter of fact Hagler's minute account does today give us some indication that such germs might easily have passed from the brook to Lausen, for the turbidity of which he repeatedly speaks is evidence of the passage of particles as small as, and possibly smaller than, the germs of typhoid fever.

Unfortunately, this was before pure cultures of bacteria were known, and no experiments were made with suspended matters as small as bacteria. The conclusion was inevitable that although filtration had in this case sufficed to remove starch grains, it had been powerless to remove the germs of typhoid fever; and, accordingly, filtration as a safeguard against disease in drinking water fell for a time into disrepute.

**The Typhoid Epidemic in Plymouth, Pennsylvania.** In 1885, the mining town of Plymouth, Pennsylvania, with a population of about 8,000, suffered from a severe outbreak of typhoid fever which involved one in every eight of the inhabitants. Plymouth received its water from a mountain brook which drained an almost uninhabited watershed. The stream was dammed at intervals and the water was stored in a series of four small impounding reservoirs. The source of the infection was traced to a citizen who spent his Christmas holidays in Philadelphia and returned home in January. He contracted typhoid, the excreta were not disinfected, but were

thrown either into the frozen creek or upon its banks within 25 or 30 feet of the edge of the stream (see Fig. 3-6). At this time the brook was frozen and remained so until spring. There came a thaw in March and the entire accumulation was washed into the brook and thence into the water-main. Three weeks thereafter cases of typhoid by the score made their appearance throughout the town. On some days more than 100 new cases occurred. In all, 1,004 cases were reported. Some estimates placed the number at 1,500, that is, 1 in every 5 of the inhabitants. There were 114 deaths. The epidemic was limited to the houses supplied with the town water or to persons who drank of the public water supply. The distinction was particularly emphasized on one street where the houses on one side had one or more cases while the houses on the other side had none at all. The former were supplied by the polluted town water, while the latter depended upon wells.

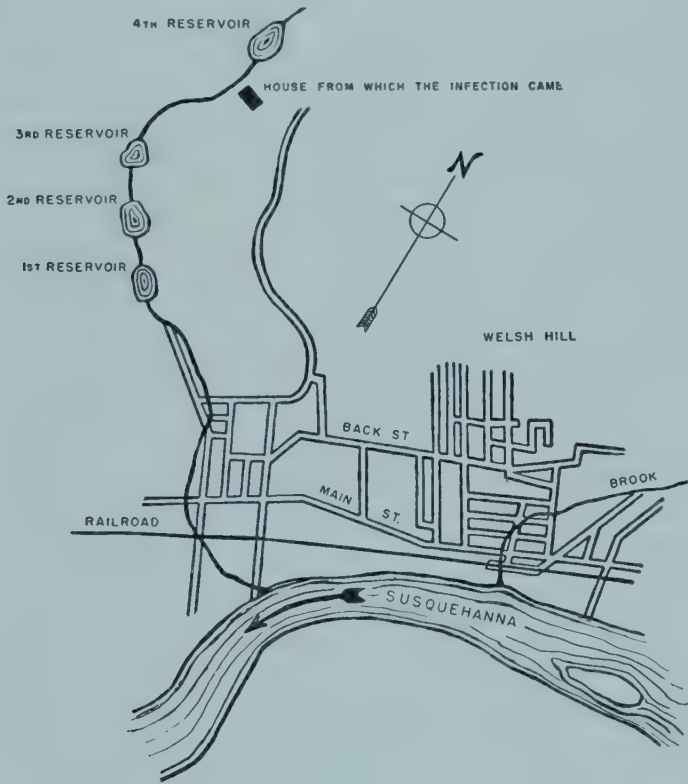


Fig. 3-6. Typhoid epidemic in Plymouth, Pennsylvania, in 1885.

This epidemic teaches the lesson that one person is sufficient to defile the "pure waters of a mountain brook draining an almost uninhabited territory." Laboratory analysis of this water prior to the thaw would not have disclosed danger, but the hazard would have been discovered by a sanitary survey. This epidemic was the first large outbreak in America where the cause was definitely traced to the water supply. It stands out sharply in the sanitary annals of our country on account of the lessons it taught and the good influence it had in stimulating other cities to safeguard and improve their water supplies.

The Typhoid Epidemic at Ashland, Wisconsin. This outbreak is cited from Harrington and is one of peculiar interest, in that, in addition to serving as an excellent illustration of the danger of using the same body of water as a place for



the disposal of sewage and as a source of drinking water, it was made the basis of an action at law, which established the liability of water companies and municipalities in case of sickness and death caused by the distribution and use of infected water.

The city's supply was derived from an arm of Lake Superior, Chequamegon Bay, upon which the city is situated. This bay, which is about 12 miles long, and has an average width of five miles, varies from 8 to 36 feet in depth. North of the city, and extending outward in a northwesterly direction, is a breakwater constructed for the protection of the harbor against northerly gales. The mouth of the water intake was located about a mile from the shore between the breakwater and the city (see Fig. 3-7). The sewage of the city was discharged further to the west and south. The currents in the bay followed the course indicated by the arrows in the figure, and carried the sewage toward the breakwater and over the mouth of the intake. This condition of affairs was brought to the attention of the company by the health boards of the city and state repeatedly, but without results. That the water was polluted was evident on mere ocular inspection, for it was often cloudy or markedly turbid. During the winter of 1893-1894 typhoid fever made its appearance in the city, and from the initial cases a disastrous epidemic developed, which led to the establishment of a model filtering plant.

The action at law referred to above was brought by the widow of one of the victims. In evidence it was shown that he lived continuously in Ashland, and drank no water other than that supplied by the water company; that previous to his sickness the disease had prevailed in the city, and that the discharges from the antecedent cases had passed into the waters of the bay by way of the city sewers. The court found for the plaintiff in the sum of \$5,000.

**The Typhoid Epidemic in Mankato, Minnesota.** Mankato (population 11,553) received its water supply from four deep artesian wells on Washington Street. Two of these wells were within from 16 to 18 feet of the pumping station. The main outlet of the sewer was at Washington Street, emptying into the river. A great flood occurred May 20 to 24, 1908. The gate in the main trunk of the sewer was let down on the night of June 24, 1908, in order to keep the river from backing up into the sewers. This caused a backing up or stasis of the sewage, which in turn backed up into a well pit of the new artesian well near the pumping station, hence sewage was pumped into the water system. Two of the other wells and suction mains were rusty and leaked and had not been properly looked after for a number of years. Then came a sudden sharp epidemic of diarrhea, June 26. Probably 2,000 persons were affected. It soon developed that the prevailing disease was typhoid fever. The epidemic began June 26 and gradually died out by Nov. 20, 1908. From July 7 to Nov. 20, 464 cases of typhoid fever were reported to the Health Officer. Of these cases, 401 were considered primary and 57 secondary or contact cases and six outside or imported infection.

This water-borne outbreak of typhoid fever is particularly instructive from the fact that Delia McKeever and Kate Flanagan, administratrices of the estates of their husbands, who died of the fever, sued the city of Mankato for damages. The city demurred to this complaint on the grounds that as a government it was exempt because it was carrying out a government function. The Supreme Court of Minnesota held that "the state is liable if negligence can be proved." The decision of the

Supreme Court in holding the city liable sets an excellent precedent which places the responsibility where it should be. Citizens are evidently as much entitled to reasonable sanitary protection as they are to police protection, or to protection from accidents at grade crossings. It is a fortunate day for preventive medicine when the principle is recognized that sanitary negligence is just as culpable as the negligence which fails to place a red flag or a red lantern to warn against a pitfall in the public highway.



Fig. 3-7. Typhoid epidemic at Ashland, Wisconsin.

**The Typhoid Epidemics of Lawrence and Lowell.** During the years 1890-1891 a typhoid fever epidemic occurred in Lowell and Lawrence, Massachusetts. This epidemic illustrates with great clearness what occurs when streams are used both as sources of water supply and as receptacles for sewage. Both cities are on the Merrimac River, which was grossly polluted by the sewage of Manchester (population 44,126), Haverhill (population 27,412), Nashua (population 19,311), Concord (population 17,004), Fitchburg (population 22,037), Newburyport (population 13,947), Marlborough (population 13,805), Clinton (population 10,424), and from other sources of pollution. In Lowell, 550 cases of typhoid fever occurred from September, 1890, to January, 1891. The epidemic was carefully studied by William T. Sedgwick, who made a most thorough investigation.

A short time after the epidemic in Lowell typhoid fever broke out in Lawrence, nine miles downstream, and rapidly increased. The relation between these two epidemics was most striking. Lowell discharged its sewage into the river, Lawrence drank the water without filtration. The climax of the Lawrence epidemic occurred about one month after that in Lowell. In 1892, there was a repetition of this episode.



Typhoid fever in Lowell was again responsible for an increase of typhoid fever in Lawrence. As a consequence of these occurrences, Lowell abandoned the river and introduced a ground water supply, while at Lawrence a filtration plant was constructed which has materially reduced the amount of typhoid fever in that city (Whipple).

**The Typhoid Epidemics of Pittsburgh and Allegheny.** These two Pennsylvania cities are situated at the junction of the Allegheny and Monongahela Rivers, where they unite to form the Ohio. In 1900, Pittsburgh had a population of 321,616 and Allegheny 129,896. Pittsburgh took its water from the Allegheny River at Brilliant Station, six miles above the junction of the rivers, and from the Monongahela River at a point three miles above the junction. Allegheny received its water supply from the Allegheny River at Montrose, 10 miles from the junction; it was drawn from a rock-filled crib, and was practically unfiltered water. Both the Monongahela and the Allegheny Rivers are grossly polluted streams, receiving the sewage from a populous watershed; in addition the sewers of the cities of Allegheny and Pittsburgh empty directly into these streams, and on account of the rapid growth of these cities much of this sewage entered the river dangerously near to the water intakes. The records of the Board of Health show that at this time there occurred annually upward of 5,000 cases of typhoid fever.

For about 10 years centering around 1900, Pittsburgh and Allegheny had the unenviable distinction of having the highest typhoid death rate of any city in this country and probably of any large city in the world. At times the rates ran above 150 per 100,000. The conditions were improved by the introduction of slow sand filtration for the city of Pittsburgh. Allegheny, which is now officially known as North Pittsburgh, was furnished in 1912 with filtered water.

**The Typhoid Epidemic at Chicago.** The Chicago epidemic is an illustration of a city using a lake water which is infected with its own sewage. The water in 1892 was taken from Lake Michigan opposite the city at several "cribs" which were one and one-half to four miles off-shore. The Chicago sewage was discharged all along the water-front, while the Chicago River penetrated the city with its north and south branches and, polluted almost beyond endurance, flowed out into the lake about midway between the upper and lower cribs. The pollution of the lake water was at times so intense that the foul river water could be traced to the intakes with the eye. This intolerable situation resulted in the building of the Chicago drainage canal, the object of which was to keep the sewage out of the lake and carry it down the Des Plaines and Illinois Rivers into the Mississippi. By the construction of this canal the flow of the Chicago River was reversed so that, instead of the sewage entering the lake and polluting the water supply, the water of Lake Michigan now flows into the Chicago River and thence, through the drainage canal, into the tributaries of the Mississippi. In other words, the sewage of Chicago, instead of entering Lake Michigan, drains to the Gulf of Mexico. During the years 1890, 1891 and 1892 typhoid fever was unusually prevalent in Chicago. In 1890, 1,008 of the inhabitants died from typhoid fever, in 1891 the death toll from this preventable disease was 997 and in 1892, 1,489. Conditions in Chicago, owing to the improvements in the water supply, including chlorination, general pasteurization of the milk supply, and an attack upon the residual typhoid as contact infection, had reduced the death rate to 0.4 per 100,000 in 1932.

The above water-borne typhoid fever epidemics have been selected as examples. Many more may be found in the literature. Whipple, in his book, *Typhoid Fever*, cites numerous instances and gives in tabular form an impressive list of such outbreaks, with reference to the literature.

The water-borne outbreaks of typhoid fever, diarrhea and dysentery which occurred in the United States and Canada from 1920 to 1930 have been analyzed by Wolman and Gorman (1931) and from 1930 to 1936 by the Committee on Water Supply of the American Public Health Association (1938). The following table is quoted from the latter source. In the United States, the largest number of

Table 3-6. Water-borne outbreaks in the United States, 1930-1936, classified as to point of pollution in water system

Point of Pollution	Outbreaks	Cases Typhoid Fever	Cases Diarrhea and Dysentery	Total Persons Affected
A. Untreated surface water	34	442	3,283	3,725
B. Untreated ground water	64	1,378	1,780	3,188
C. Contamination reservoirs and cisterns	4	17	196	213
D. Inadequate control over water purification	15	608	9,678	10,286
F. Contamination in distribution system	15	287	1,975	2,266
G. Contamination in collection or conduit system	2	5	0	5
H. Miscellaneous	36	443	1,969	2,412
TOTAL	170	3,180	18,881	22,095

Adapted from Rep. Comm. on Water Supply, Am. P.H. Ass'n, Year Book, Am. Pub. Health Ass'n, 28: Table VIII, 1938.

outbreaks of cases of typhoid fever was due to the use of untreated ground water supplies, this being the cause of 64 out of 170 outbreaks. Next in importance were untreated surface waters, rivers, small streams, ponds and lakes, which account for 34 out of 170 outbreaks. It is highly significant from a public health standpoint and important to note that errors in treatment of water and subsequent delivery of this water to the consumer caused 30 outbreaks. Bathing in polluted water is thought to have caused only three of the 170 outbreaks. The evidence on which this latter conclusion is based is not given in detail.

**Other Modes of Transmission.** ICE. Ice may, under exceptional circumstances, occasionally be the vehicle by which typhoid bacilli are transferred. Freezing does not kill *B. typhosus*, but there is a great quantitative reduction not only in the act of freezing but also during storage; hence the danger is greatly lessened. The only suggestive outbreak of typhoid fever attributed to ice was reported by Hutchins and Wheeler in 1903 in the St. Lawrence Hospital three miles below Ogdensburg. A few other instances in which ice is believed to have conveyed the infection have been reported, but are based upon flimsy evidence. The fact that natural ice is usually stored many weeks or months before it is used is a sanitary safeguard. Manufactured



ice made from distilled water and handled with cleanly methods is above reproach.

**MILK.** Milk usually becomes contaminated on the farm from a case or a carrier. It may also become contaminated in transportation, at the city dairy, or in the home. Milk-borne outbreaks are practically always due to raw milk; there is no case on record of such trouble coming from properly pasteurized milk. On account of the almost universal custom of boiling milk in European and tropical countries, milk outbreaks are rarely found in these regions.

In the United States, raw milk has been a frequent vehicle of distribution of typhoid infection in the past (see Table 22-2, page 868). While the potential danger is still present, milk-borne epidemics have become increasingly rare in recent years as the sanitary quality of milk supplies has been improved and pasteurization has become almost universal.

**MILK PRODUCTS.** Fresh milk products, such as cream, ice cream, butter and buttermilk, and fresh cheese, may contain the typhoid bacillus, and, if they are not subjected to a pasteurization process, are occasionally media of communication.

*Cream* contains more bacteria than the milk from which it is taken. The use of infected cream in coffee, on cereals, etc., is sufficient to cause the disease. As a rule, coffee in the cup is not hot enough to kill the typhoid bacillus, if present in the cream added.

Mitchell working in Rosenau's laboratory found that *S. typhosa* survives in ice cream for from 12 to 39 days. Lumsden (1917) traced the Birmingham, Alabama, outbreak in 1916, and another in Chattanooga, Tennessee, to ice cream. An outbreak at Helm, California, was found by Cumming (1917) to be due to ice cream.

Bruck has shown that the typhoid bacillus will live in butter for 27 days.

The acidity and overgrowth of other organisms in *buttermilk* is said to inhibit growth of the typhoid bacillus in 24 hours. In *cheese* the time of fermentation, antibiosis, aging, etc., lessens the likelihood of survival of the typhoid bacillus. Fresh cream cheese, such as cottage cheese, may be responsible for an occasional case.

**OYSTERS, MUSSELS AND SHELLFISH.** The first outbreak of typhoid fever established as due to this source was investigated by Conn at Wesleyan University, Middletown, October, 1894. Twenty-five cases were attributed to eating infected oysters; four died. Not all of those who took sick had clinical typhoid fever. Some had gastro-intestinal disturbances with illness lasting but a few days. About one quarter of those attending the dinners at which the oysters were served were made ill.

L. W. Darra Mair (1909) showed that much of the typhoid fever in Belfast, Ireland, from 1897 to 1901, was due to eating cockles and mussels taken from sewage polluted water. The amount of the fever diminished markedly and its seasonal prevalence was changed by betterment of the shellfish situation.

In Brighton, England, J. T. C. Nash (1909) proved that much of the typhoid fever in the Borough of Southhead-on-Sea prior to 1899 was due to infected oysters. There was a sharp reduction in the amount of fever when the foreshore fisheries were stopped, and almost a cessation of all cases when attention was given to all shellfish, including the improved laying and cooking of cockles. The largest outbreak due to oysters occurred in the United States in 1924. Oysters become dangerous when consumed soon after taking them from a polluted bed, or when floated or bloated in infected water. For further discussion of this topic, see page 908.

**FRUITS AND VEGETABLES.** Vegetables, such as celery, lettuce, watercress and radishes, partaken raw, and grown on land fertilized with fresh night soil, may be infected, and this probably accounts for an occasional case. Vegetables so contaminated are not made safe by the ordinary methods used in preparation of such food for table use. In large cities it is practically impossible to trace this source of infection. It therefore remains more a suspicion than a conviction.

**FLIES.** The common house fly (*Musca domestica*) may convey the infection of typhoid. The typhoid bacilli may be smeared upon the feet or other parts of the insect, or may live in the intestinal tract and pass in the dejecta in almost pure culture. Some species of flies live, feed and breed in fecal matter and decomposing organic substances of all kinds. It is easy to see how they may convey infections from this source to our food, lips or fingers. Alice Hamilton isolated typhoid bacilli from 5 out of 18 house flies captured in Chicago in the privy and on a fence near a sick room during a local water-borne epidemic. It has been shown experimentally that living typhoid bacilli may remain upon the bodies of flies for as long as 23 days. Special attention to the role played by the fly was given by Reed, Vaughan and Shakespeare in their studies of the prevalence of typhoid fever in our army camps in 1898. They concluded that flies undoubtedly served as carriers of the infection and attributed about 15 per cent of the cases to this mode of communication. They found that "flies swarm over infected fecal matter in the pits and then deposit it and feed upon the food prepared for the soldiers at the mess tents. In some instances, where lime had recently been sprinkled over the contents of the pits, flies with their feet whitened with lime were seen walking over the food." The danger from fly transmission varies very much, and depends upon circumstances. In a camp it is considerable; in a well sewered city the risk is diminished. In the Washington studies no relation was found between fly abundance in the summer of 1908 and typhoid prevalence. The danger of typhoid from flies in cities has doubtless been overstated. However, if infection were transmitted only occasionally, the suppression of flies would still be quite worth while.

**DUST.** Typhoid bacilli soon die when dried, especially when exposed to the sun and air. Dust-borne infection in this disease must be rare.

**FOMITES.** The infection may be conveyed upon soiled linen, blankets and other objects. It was believed by Reed, Vaughan and Shakespeare that the clothing, blankets and tents in the Spanish-American War became infected and were a prime factor in spreading the disease. The danger of fomites contaminated with fresh infection is real, and emphasizes the importance of disinfecting bedding, towels, handkerchiefs, body linen and other fabrics.

**SOIL.** From a study of the longevity of *S. typhosa* in various kinds of soil, Beard (1940) concluded that the most important apparent factor determining survival was moisture. Fifty per cent of typhoid bacilli will probably die during the first 48 hours. Survival of the remainder may extend over a period of months, depending upon conditions.

**CONTACT.** "Contact" is a convenient term to indicate the spread of infection directly or indirectly as a result of close association between the sick and the sound. Actual contact is not necessarily implied. The term is used to indicate the transfer of the infection through a short intervening space in a brief period of time. Thus, the infection may be passed from one to another through soiled hands, remnants of



food, infected thermometers or tongue depressors, contaminated towels or other fabrics; cups, spoons, glasses, etc. The infection may also be spread in the household by flies, fingers, and various other means, usually difficult to trace, and which are, therefore, all included under this general designation. Regarded in this light, contact plays a large role in the spread of the disease.

Extensive municipal outbreaks have been reported as largely or entirely due to contact transmission. Winslow, in 1901, studied such an outbreak in Newport. Others have been reported from Knoxville, Winnipeg, Springfield, and from Germany and England. Koch regarded the spread of typhoid in Trier in the light of contact infection. Freeman thought that the majority of outbreaks in the smaller towns of Virginia were due to this cause. Extensive outbreaks in institutions are often due to contact with missed cases or carriers. "Flies, fingers, and food" (Sedgwick), and "dirt, diarrhea, and dinner" (Chapin), which too often get sadly confused, explain the occurrence of many a case of contact infection.

#### TYPHOID VACCINES

**Preventive Typhoid Inoculations.** Our knowledge of inoculations against typhoid fever began with the work of Pfeiffer and Kolle, who inoculated two volunteers in 1896. About the same time, Almroth Wright inoculated several persons, and in 1898 continued the work upon an extensive scale in India upon 4,000 British soldiers. In 1900, during the Boer War, Wright, together with Leishman, prepared a vaccine and supervised the inoculation of 100,000 British troops. The results in India were quite encouraging, but for various reasons the same procedure in South Africa was not as satisfactory as had been anticipated. Prophylactic inoculation on the advice of Koch was used by the Germans in the Herero campaign in southern West Africa in 1904. The prophylactic was voluntary and only about half of the command (7,287 men) availed themselves of it. The results, while good, fell short of expectations.

In the United States, production of typhoid vaccine for use in the Army was initiated by Brig. Gen. Frederick Russell in 1908. The original procedure adopted was a modification of the English and German methods, the aim being to make a sterile standard suspension of typhoid bacilli with their essential immunogenic constituents as little changed as practical. Typhoid inoculations were recommended as a voluntary protection in 1909 and were made compulsory in 1911, and have been required by Army regulations since that time. Subsequently, the development and improvement of methods of production and administration of typhoid vaccine for use in the United States has resulted very largely from studies conducted in the research laboratories of the Army Medical School. The objective has been to develop a vaccine which would afford a maximum degree of protection with a minimum frequency of unpleasant reactions from its administration. In other words, a balance was sought between high immunogenic potency and low toxicity. The history of the changes and the results obtained in the prevention of typhoid fever by the use of vaccines produced as modified from time to time has been reviewed by Siler and his associates (1941).

The principal modifications introduced have been related to the selection of strains for inclusion, the numbers of organisms per ml. of vaccine, the technic of inactivation by heat and chemicals and the dosage injected. Originally, the Rawlings

strain of *S. typhosa* was used in preparation of the vaccine. As a result of studies of strains suitable for the production of vaccines of optimum antigenic composition, with particular reference to the Vi antigen, in 1936 a new strain (#58) of *S. typhosa* was substituted. Originally, a monovalent typhoid vaccine was produced. During World War I, because of the possibilities of exposure under field conditions, strains of *S. paratyphi* A and *S. paratyphi* B were included in the vaccine, so-called triple vaccine or T.A.B. Since that time, practice has varied with regard to the inclusion or exclusion of paratyphoid organisms. The Army regulations now in force require the use of triple vaccine.

In the standard procedure, typhoid bacilli are cultivated on veal infusion agar, harvested after 18 to 24 hours of incubation at 37° C by emulsification with normal saline, killed in a water bath at 56° C. The suspensions are then standardized as to bacterial content. The method used for this estimation is much more accurate than it was formerly. The content of the triple vaccine now in use (Longfellow and Luippold, 1943) is as follows: 1,000 million *S. typhosa*, 250 million *S. paratyphi* A, and 250 million *S. paratyphi* B per ml. of vaccine. The pH of the preparation is adjusted to approximately 7.2, tricresol 0.25 per cent is added as a preservative.

Since infections with *S. paratyphi* A and B are extremely rare in the United States, the monovalent *S. typhosa* vaccine is advised for the civilian population.

Initial vaccination consists of a subcutaneous injection of three 0.5 ml. doses of vaccine administered at intervals of seven to 28 days. Reactions from this dosage are usually moderate. There is always some local tenderness at the point of inoculation, with a variable amount of swelling, edema and pain. When the injection is made in the upper arm, the axillary lymph glands usually become large and painful. In a small proportion of individuals a systemic reaction, varying in severity, follows within a few hours and is manifested by headache, chills, fever, lassitude, muscular pains, malaise, nausea and urticaria. An indication of the frequency of local and systemic manifestations is afforded by Table 3-7 based on Luippold's (1944) observations on 115 medical students who had received T.A.B. vaccine. The systemic symptoms usually subside in 24 hours.

Concerning the protection conferred by an initial course of three injections of typhoid vaccine, it can be said that it develops gradually, reaching its maximum a week or two after the third injection and then gradually decreases. How long it lasts is uncertain. Laboratory procedures, such as the titration of agglutinins in the blood serum and mouse protection tests, afford an indication of immunity (Luippold and others, 1947) but have not been correlated in an exact manner with protection from attack in a human being naturally exposed. There are many factors involved in immunity to typhoid infection which are not understood.

The evidence available indicates that to maintain a maximum degree of protection against typhoid it is advisable to revaccinate or inject a stimulating dose every two or three years. In the United States Army, revaccination by stimulating doses is required annually. For this purpose, a subcutaneous injection of 0.5 ml. of vaccine or an intracutaneous injection of 0.1 ml. of vaccine is given.

The degree of protection afforded by typhoid vaccination is still a matter of some discussion (Edsall, 1949). The question must be answered by human experience under natural conditions of exposure. Much of the evidence has been derived from observations on the association of its use in a military organization, with the sudden



Table 3-7. Summary of local and systemic reactions following subcutaneous injections of the standard dosage (0.5, 1.0, and 1.0 ml.) of T.A.B. commercial vaccine to 115 persons

Dose of Vaccine	Local					Systemic								
	Average Area of Hyperemia in Sq. Cm.	Degree of Tenderness				None	Head-ache	Chills	Fever	Lassi-tude	Muscu-lar Pains	Malaise	Nausea	Urti-caria
		None	Slight	Mod-erate	Severe									
1st	51	0	35	51	29	67	22	6	11	17	8	10	1	0
2nd	65	0	30	46	39	67	15	4	12	16	12	15	1	1
3rd	45	5	76	24	10	99	7	2	3	5	4	4	0	0

Adapted from Luippold, G. F., Am. J. Pub. Health, 34:1151, Table 12, 1944.

and abrupt fall in the typhoid rate, or with the low rate in comparison with other population groups not so protected. In such comparisons one cannot be sure that the exposure to infection is equal or that other factors may not be responsible for the differences. There have been a few observations on civilian groups in which one could be reasonably sure that the immunized and nonimmunized groups were equally exposed (Murphy and others, 1944; Duncan and others, 1946).

Furthermore, in evaluating this evidence, two elementary principles must be borne in mind. The findings of a particular study do not apply to typhoid vaccine in general but to the specific product and method of administration and circumstances of exposure which obtained with reference to time since vaccination. The second is the fact that no immunizing agent can ever be expected to give 100 per cent protection at all times. Its efficacy is relative to the size of the infective dose and the virulence of the particular strain of the micro-organisms to which the group is exposed. There will always be an infective dose or an interval since inoculation which will overcome whatever protection was induced by vaccination procedure employed. The occurrence of cases of typhoid fever among persons who have been inoculated means only that the vaccine does not always protect. This has been known for no less than 35 years. On the other hand, there is a considerable amount of evidence, direct and indirect, which supports the concept that vaccination against typhoid with the optimum methods of preparation and administration now known, affords a considerable degree of protection for an indefinite time, provided it is maintained by stimulating doses.

Preventive typhoid inoculations involve no risk, and are especially applicable to those unduly exposed to the infection, such as nurses, hospital attendants, physicians, travelers, soldiers in camps, and individuals in the family of a case or carrier.

Typhoid vaccination should be mandatory in asylums and other custodial institutions. The method is serviceable for general use among the public in endemic foci, but it is a question whether this artificial method of acquiring immunity would serve as good a purpose in the end as fighting the disease along the lines of general sanitation, which has been so successfully done in many countries. It would certainly be a mistake to immunize the population with this artificial method to the neglect of general sanitary improvements, such as good water, safe milk, fly suppression, cleanliness and personal hygiene. Because a person has received the protection afforded by typhoid inoculations is no reason for reckless disregard of other prophylactic measures. *Typhoid inoculation is not a substitute for sanitary precautions.*

**Management of a Case so as to Prevent Spread.** Success depends upon an early and accurate diagnosis. All cases of typhoid fever and all cases suspected of being typhoid fever should be isolated. This does not mean imprisonment in a lazaretto. *The proper place to care for typhoid fever is in a suitable hospital.* A private home is a poor makeshift for a hospital, and it is unreasonable to turn a household into a hospital for four to eight weeks or longer. Where this becomes necessary, the room in which the patient is treated should be well ventilated, and should contain no unnecessary furniture, curtains, carpets, etc. It should be near the bath and must be well screened and kept scrupulously clean, dry sweeping and dusting prohibited. Exposed surfaces should be wiped off daily with a disinfecting solution. Dogs, cats and pets of all kinds should be kept out of the sick room.

The case should be reported to the health authorities without delay. Visiting



should be prohibited and no one allowed in the sick room except those who have duty there. The patient should be nursed by one skilled in the technic of preventing the spread of infection.

The health officer should send an epidemiologist or a public health nurse without delay to the premises to instruct and to see that all necessary measures are being taken. The origin of the infection should be studied so as to prevent further spread from that source.

The disposal of the stools, urine, sputum, and other discharges is of the first importance. The methods used will vary with circumstances. Differences in the facilities available will determine what procedures are safe and advisable for the community involved. Disposal of untreated urine and feces by water-carried sewage is a safe procedure in some areas, if legally permissible. Where this does not seem to be advisable, some form of chemical disinfection must precede disposal. For the urine, sufficient bichloride may be added to make a 1:1,000 solution, or carbolic, 2.5 per cent, or formaldehyde solution, 10 per cent, and allowed to stand one hour before discarding. Stools may be disinfected with bleaching powder, 3 per cent; milk of lime (1:8); cresol, 1 per cent; carbolic acid, 5 per cent; formaldehyde solution, 10 per cent; or unslaked lime and hot water. The discharges should be received in a glass or earthenware vessel containing some of the germicidal solution. Then add more of the solution so that it shall be present in twice the volume of the excreta to be disinfected; disintegrate the masses thoroughly and let stand at least two hours, protected from flies. Masses are so difficult to penetrate that they must be broken up thoroughly with a wooden paddle. It takes a strong carbolic solution 12 hours to penetrate the interior of a small fecal mass; larger masses are impenetrable to most germicides. Urinals, bed pans, etc., should be scalded or washed in a disinfecting solution, and when not in use should contain this solution. The sputum should be burned.

The patient should have his own dishes, cups, spoons, glasses, etc., which should be kept and washed apart; they should be scalded after each use. Remnants of lunch, especially meat, milk, gelatin, broths, and other organic food in which the infection may live and even grow, should not be eaten by others. Such remnants may be burned or first boiled and then discarded. Those who nurse the sick should keep out of the kitchen on account of the risk of contaminating the food.

Handkerchiefs, towels, sheets, nightgowns and all fabrics used about the patient should be disinfected by boiling.

Milk bottles must be kept out of the sick room. In any case, they should be scalded before leaving the house and again disinfected before returning to the dairy.

The thermometer should be kept in formaldehyde solution, alcohol or other suitable germicidal solution. Rectal tubes, especially in hospital practice, must be carefully disinfected each time before using. Individual instruments are preferable. For children inexpensive toys and books may be provided during convalescence and then destroyed.

The nurse must protect herself as well as others. Every time the patient is bathed, his mouth cleaned, or his buttocks washed, the hands must be washed in soap and water and disinfected. The nurse must exercise especial care if she is to go to the kitchen or to the ice box, etc., as is frequently the case in private houses, where a special diet kitchen cannot be provided.

The nurses, physicians, ward attendants, familial associates, and others particularly exposed should be protected by preventive typhoid inoculations. The physician should be quite as careful as the nurse, not only that he may not carry the infection to himself or other patients, but also that his practice may serve as a stimulating example.

At the conclusion of the case a general cleansing and disinfection of the room and its contents should be practiced, followed by sunning and airing.

Convalescents should not be given liberty until the danger of bacillus carrying has passed. This may be determined only by bacteriologic examinations of the stools and urine. Three successive negative cultures of feces and urine specimens, collected not less than 24 hours apart and not earlier than 7 to 10 days after the patient becomes afebrile are required to determine that the carrier state is not established.

**Summary.** The decrease and gradual disappearance of typhoid fever from the United States and other advanced countries is an outstanding example of control by preventive medicine and environmental sanitation. The steps to this achievement are well known. The first requirement is to eliminate dissemination through public water supplies to urban populations. In the United States improvement began in the 80's and 90's and took place in one city after another as practical methods of purification of water developed. Particularly important in this connection was the introduction of chlorination about 1908 and gradual enforcement of standards of water safety based upon adequate engineering consideration of sources of supply, improved methods of treatment and purification, safeguarding the distribution system, and the use of frequent chemical and bacteriological analyses. These measures were gradually extended from the cities to the smaller towns and villages through the activities of sanitary engineering divisions of the state health departments. Along with the improvement in water supplies came the extension of water-borne sewage systems. Common practice during the latter part of the nineteenth century was to discharge raw sewage into streams and ponds and lakes. In the heavily polluted areas surface streams, ponds and lakes become open sewers. Gradually, this situation has been ameliorated by the installation of sewage treatment works; much still remains to be done. Second only to water as a vehicle of wide dissemination were the common milk supplies. At the turn of the century these were practically without sanitary regulation; a low standard of cleanliness prevailed with regard to milk distribution; the product was delivered to customers in the raw state. Gradually, during the past half century adequate standards of cleanliness have been set up and enforced, production and distribution have been brought under sanitary supervision and more than 95 per cent of the supplies in this country are pasteurized before delivery to the customer. Similar improvements have been effected in protecting milk products. With the elimination of milk-borne and water-borne typhoid in the cities, prevalence rates declined rapidly leaving so-called residual typhoid in the areas adjacent to the cities and in the rural districts. To provide safe water and proper sewage disposal for private homes was a slower process but has gone on continuously. Decrease in the fly nuisance as the horse was superseded by the motor driven vehicle undoubtedly played a role. There was an increasing use of hospitals for the isolation of clinical cases of typhoid fever with consequent reduction in frequency of contact infections. The opportunities for dissemination of fecal material from person to person was reduced gradually by the improvement of home hygiene through education of the



public and better economic conditions. Toward the latter part of the period under consideration, the use of prophylactic vaccine undoubtedly became a factor but its application was limited geographically and to especially exposed groups.

The problem in this country has now become one of small towns and rural districts, of sporadic cases and focal outbreaks. Control has become increasingly a matter of prompt diagnosis and isolation of patients for the protection of contacts, and the tracing of sources of infection. The discovery and supervision of carriers has become an important health department function.

The ultimate reservoir of infection with typhoid is the number of carriers in the population. Their numbers are being decreased through deaths more rapidly than they are being replaced by new carriers arising from cases. The balance is against the survival of the disease and ultimately elimination from large areas is to be anticipated.

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## SALMONELLOSIS

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Salmonellosis is a convenient etiologic term to describe a variety of conditions of man and many animal species. The causative agents are Gram-negative, lactose-negative rods, grouped together on biochemical and serological grounds into the genus *Salmonella*. Most of them are fairly common parasites in the tissues of sick animals and birds, but they abound particularly in the intestinal tracts of these hosts, both healthy and diseased. Salmonellosis may, on occasion, result from the ingestion of food containing the organisms; but since this is only one of numerous modes of spread, such qualifying terms as "food infection" seem undesirably restrictive in a general context.

In humans, the clinical picture of salmonellosis ranges from severe enteric fever, septicemia, dysenteric syndromes and such focal manifestations as pneumonia, meningitis and arthritis, to gastroenteritis, trivial diarrheas, and the healthy carrier state. Clinically and epidemiologically, there are good reasons to consider typhoid fever (*Salmonella typhosa*) separately, but the reasons for a blanket segregation of the so-called paratyphoid fevers are less cogent, and in the following discussion, diseases caused by *Salmonella paratyphi A*, *S. paratyphi B* or *S. paratyphi C* will be singled out from other salmonellosis in certain particulars, and lumped with them in others, as the facts require.

## SOURCES AND SPREAD

There are five main threads in the development of our knowledge on this subject. The first *Salmonellae* to be identified came from material in an outbreak resulting from the consumption of the flesh of a fatally infected animal. For over 50 years since, the bulk of the literature on salmonellosis has been oriented with reference to the problem of "food poisoning." In fact, salmonellosis has until recently been considered practically synonymous with "food poisoning." A second element entered the picture as more was learned about the role of the *healthy carrier* in typhoid



fever. Much effort has been spent attempting to evaluate the same factor in other *Salmonella* infections. Third, much has been made of the part played by such *vectors* as rodents, flies, roaches, and lately even ticks and fleas. Fourth, recent work has suggested that *household pets* may serve as a significant source of salmonellosis. Finally, while in most salmonelloses the secondary attack rate is not very high, nevertheless the *sick individual* himself may be a danger to others, particularly (as is also the case with carriers) in such environments as food handling establishments, mental hospitals and pediatric wards. Infants have acquired *Salmonellae* at birth, as a result of an infection in the mother.

It must be emphasized that the all important common denominator among the sources listed above is *human or animal feces*. With rare and not always well documented exceptions, such as naso-pharyngeal exudate and the flesh of animals following tissue invasion, *contamination of food by feces* or any other mechanism which results in the *ingestion of fecally contaminated material* is the gist of the matter. *Salmonellae* are primarily enteric pathogens, and if one bears this simple epidemiological principle in mind, the complexities of the sources and spread of salmonellosis tend to disappear.

**Food.** Prepared food containing *Salmonellae* represents a very late link in the chain of transmission. It may contain the organisms because it has been contaminated at any stage in its preparation or processing, or it may contain them because the animal from which it came was infected with *Salmonellae*, whether symptomatic or not. Examples of the first type are contamination by sick or healthy humans harboring *Salmonellae*; by sick or healthy vectors; or from utensils or other food. One example of the second type is the egg which contains *Salmonellae* from the tissues or feces of the hen. Another example is the epidemic of acute diarrhea following the consumption of meat from a sick animal. Today, however, since in many parts of the world, flesh from obviously sick animals is infrequently consumed, and since the consensus is that heavy invasion of the tissues seldom, if ever, occurs in the absence of obvious clinical disease, a much more important problem concerns healthy animal intestinal carriers. The problem assumes major proportions when food is processed in bulk or by assembly line technics, and contamination of the meat of many carcasses occurs from the gut contents of a single carrier animal. This distinction between antemortem infection and postmortem contamination is often highly important in epidemiological studies, particularly with regard to control.

Thus, meat is a major source of salmonellosis. Pork and poultry are the most frequent culprits, and both have been definitely convicted in countless outbreaks. Both swine and fowl suffer from symptomatic salmonellosis and both species are capable of assuming the carrier state. Historically, pork was one of the earliest to be accused, and as recently as 1936 a law suit was decided against an eating establishment on the basis that pork was included in the meal, whereas, no importance was attached to the fact that the victim's previous meal included roast fowl, which, in the light of our present knowledge, is at least as likely to have been the vehicle of infection.

**POULTRY.** Information on the prevalence of infection with *Salmonellae* in domestic animals is meager, since the majority of studies have been concerned with sick animals only. The few studies which have been made on domestic animals in the normal population indicate that practically all animal species are positive. The fre-

quency distribution of the various sero-types correspond in general rather closely with the types found in man. To illustrate: 1.3 per cent of normal chickens in Mexico had *Salmonellae* in the intestinal contents. A sample of normal chickens in Texas showed 0.75 per cent positive for *Salmonellae* in their feces. The studies on turkeys indicate that these birds are possibly more likely to carry the *Salmonella* organisms than are chickens. A number of outbreaks of human disease have been attributed to roast turkeys. A special factor may be the larger size of this bird which makes it more difficult to cook thoroughly. The importance of contamination of meat during processing is illustrated by a culture study showing that a single infected turkey carcass contaminated many other carcasses during dressing. This contamination was found to largely disappear in a few days, but not if the carcasses are frozen. Ducks commonly have salmonellosis and numerous epidemics have been traced to these birds.

**Hogs.** There is evidence that perhaps 10 to 15 per cent of normal hogs are healthy carriers. Many independent studies of the mesenteric lymph nodes of hogs on the slaughter house floor have yielded closely similar results, ranging from 5 to 20 per cent. Rates up to 70 per cent of individual lymph node involvement have been observed in sick hogs discarded at the slaughter house. Here is other evidence of contamination during processing: in one abattoir in which 20 per cent of the lymph nodes were positive when collected aseptically, the rate was 60 per cent when ordinary slaughter house methods were employed.

**EGGS.** Duck eggs as a source of outbreaks of salmonellosis are only too well known, especially in Europe. The suggestion is sometimes made that the relatively unhygienic habits \* of ducks compared with those of chickens may have something to do with the particular importance of duck eggs as compared to hen's eggs.

Recently, however, hen's eggs have been incriminated with exceptionally strong evidence in various outbreaks. Culture studies on market eggs have been a source of information. It is also known that experimentally infected chicks (the survivors) will carry *Salmonella* for a long period, that 4 to 10 per cent of the eggs of the survivors will be positive in either shell or meat, that known positive flocks produce up to 30 per cent positive shells and 1 per cent or more positive meats. Opinion, it should be noted, is divided as to the relative importance of shell vs. egg meat, though the consensus points to the shell as definitely the more important. The shell, the yolk and the white of the egg may all contain *Salmonellae*. The organisms have been shown to survive up to three weeks at room temperature, and as long as 30 days in duck eggs. Dirty-shell eggs are about four times more frequently positive than clean eggs, and about twice as frequently positive as washed dirty eggs. This, of course, is in agreement with the known fact that healthy chickens are frequently fecal carriers. In one survey, 0.6 per cent of storage shells were positive. Washing the eggs, especially in cool or cold water or immediately after laying, increases the likelihood of shell penetration, as indeed do any conditions of increased environmental moisture. Penetration is greater in the incubator than at room temperature. Clean eggs almost always have sterile meats; washed dirty eggs often do not, though they may be marketed as "cleans." Around 5 per cent of dirty eggs may have positive meats and around 15 per cent of dirty eggs may have positive

\* They "practice their amours and lay their eggs in any old ditch." (Lecoq.)



shells.\* Eighty per cent of experimentally positive eggs hatched into positive chicks, none of which however showed signs of disease and many of which continued to carry the organisms. From the poultryman's point of view the major problem centers around the incubator with its environment of increased moisture and temperature in which *Salmonellae* have been shown experimentally to survive as long as 111 days.

Powdered egg is undoubtedly a more serious matter than the fresh egg. A consistent figure of around 30 per cent positive for *Salmonellae* other than pullorum is the rule for samples from commercial powdered egg factories. The number of organisms, however, is quite low and apparently no multiplication occurs in the dry powder. It follows, therefore, first that egg powder with low moisture content is safer than egg powder with high moisture content, and secondly, that significant danger arises when reconstituted egg mixture is permitted to stand at more than 15° C, where the organisms can multiply. The relative importance of shell vs. meat in the egg powder problem is unsettled but opinion is leaning towards shell. It is proven that the multiplication of bacteria does take place during the processing of eggs, especially when unnecessary lags occur or "pockets" of mixture collect. Organisms disappear fairly rapidly from egg powder on storage, but less rapidly when the powder is stored cold.

**OTHER FOODS.** The problem in other foods is mainly one of contamination. In the past many outbreaks have been attributed to milk and cream products, including synthetic cream. The evidence incriminating milk is not very good and many of the outbreaks were reported before any importance was being attached to the use of eggs in the same milk products. The evidence for the secretion of *Salmonellae* in cow's milk is equivocal. *Salmonellae* have occasionally been found in the udder, but there is no instance of milk collected under sterile conditions being positive on culture. Moreover, cows are well-known fecal carriers, and contamination from that source is probably the rule in the rather rare instances where milk is incriminated.

*Salmonellae* have been shown experimentally to survive for weeks or months in canned fruit, butter, cheese, brine, cereals, bread and they can live for many days on kitchen utensils. They will multiply in milk at 15° C and they will survive at freezing temperatures. Fish smoked or pickled in the ordinary way may contain infective amounts of *Salmonellae*. Dilution of some food seems to favor survival.

For many years, in the face of an outbreak of salmonellosis, epidemiologic investigation focused on the food immediately before consumption, that is, on the last link in the chain of transmission. Excluding the rare case in which a sick animal was slaughtered for food purposes, it was usually assumed that either a human carrier was involved or an animal such as a rat or mouse. It is only fairly recently with the increasing realization that the *original animal source is important* and that *healthy animal carriers are fairly common*, that we have begun to look further backward in the chain of transmission, but at this time we do not have the necessary information to compare the relative importance of different food sources and means of spread, beyond the perhaps crude generalization that pork, fowl, duck eggs, and

\* Throughout this section, as above, figures refer to *Salmonellae* other than pullorum. Incidentally the pathogenicity for humans seems to be well established by one or two well studied outbreaks; however, the degree of pathogenicity is extremely low, and outbreaks attributable to pullorum must be correspondingly rare.

powdered eggs appear to stand out far above all other food as immediate sources; and that ultimately the food is most often contaminated by the feces of the animal in question. Food sources thus defined appear at this time to far outweigh contamination by vectors and—except for certain sero-types—to exceed food contamination by carriers.

**Rodents and Arthropods.** *Rats and mice* have been traditionally considered the main culprits in the spread of salmonellosis but data are fragmentary and disconnected. Rats and mice may suffer salmonellosis often and continue to carry the organisms as healthy carriers for months or for life. There are gallbladder carriers among rats. Discovered prevalence rates vary from 1 to 20 per cent, and this variation seems to depend largely on whether the animals are trapped in a packing house or restaurant area or elsewhere where they have access to *Salmonella* contaminated food. Another variable depends on whether fecal studies are made or cultures of the blood and viscera. The latter are consistently higher, but the former are more directly related to the problems of human disease. It is difficult to find a single outbreak convincingly attributed to one of these animals. Too many investigators stop studying a *Salmonella* case as soon as they find a mouse pellet in the house or get a positive culture from an animal. The possibility must always be borne in mind that the animal and the human case may have been collaterally infected from a common source. As of 1950, some commercial rat poisons were still incorporating *S. enteritidis* as the rodenticide. This practice is indefensible since it is not an effective rodenticide and does create a reservoir of rat carriers.

**FLIES.** A significant amount of air-tight evidence against flies is not easy to collect. The experimental case, however, against the fly is proven to the hilt. *Salmonellae* have been isolated from the bodies of flies, from maggots and from fly eggs. It is known that eggs hatched in contaminated mash then washed antiseptically will produce infected adult flies. The house fly can carry *Salmonella enteritidis* throughout its lifetime. *Salmonellae* have been isolated from flies caught in their natural environment. On the other hand, in a study designed to show the effect of fly control on diarrheal disease in Texas, the degree of control attained had little if any effect on *Salmonella* prevalence. This stands in marked contrast to the effect on *Shigella* prevalence since in this group of organisms a significant reduction was demonstrated.

**ROACHES.** Experiments have shown that several species of roaches feed readily on human feces, and that when they are artificially infected with *Salmonellae* about half die and perhaps one-third remain infected for a month or more during which they intermittently excrete the organisms in their feces. Roach pellets may remain positive for 199 days at room temperature. The exterior surfaces of a roach may remain positive from a single contamination for 78 days. Roaches can transmit the disease to other roaches and it is worth recalling that the fecal pellets of some common species are large enough to be mistaken by the naive for mouse droppings.

Wood ticks have been shown to be infectable with *Salmonellae* and capable of transovarian transmission to their offspring. Dog ticks have been more or less convincingly incriminated in epidemics of *Salmonella* enteric fever in kennels. Many other animal species are known to harbor *Salmonella*, including armadillos, snakes, and small birds.

In summary, the case against arthropods and rodents is circumstantial and the



lack of direct evidence in itself indicates that they probably play a minor part in the spread of human salmonellosis.

**Pets and Non-Food Animals.** One of the latest developments in the *Salmonella* field is the increasing interest in dogs and cats as a source. This development is related to the shift in emphasis from epidemic disease, especially food poisoning, to endemic sporadic cases which are believed by many to constitute on the whole a more serious problem. Several outbreaks involving single cases or groups of cases in a household have called attention to the simultaneous or preceding infection of the family dog. The animal is sometimes symptomatic with diarrhea or other disease and sometimes is asymptomatic. In Australia, a large outbreak was related on epidemiologic grounds to a preceding outbreak of typhimurium enteritis in cats. Salmonellosis in cats and dogs may cause abortion, diarrhea or a variety of symptomatic and asymptomatic conditions.

A few surveys are available. Eighteen of 100 dogs in Michigan were excreting *Salmonella* in their feces. Most were subclinical cases or convalescent or healthy carriers. In Texas, over 3 per cent of 1,100 unselected dogs and over 3 per cent of 600 cats had positive fecal cultures. In this same survey, a significant deviation in one town from the sero-type distribution found in all surrounding towns in humans was duplicated in the animal population with very impressive correspondence. There was, in addition, an individual case of a child and a cat with which the child played, both harboring a previously unreported type of *Salmonella* not found in any other person or animal during this survey. One survey of many dog kennels has shown up to 100 per cent fecal excretors. In London, a sample of well dogs showed five positive out of 500, and seven of 500 cats.

Salmonellosis is not widely recognized by veterinarians as an important disease of dogs and cats. There are probably few cases in relation to the number of carriers. There is a fertile field for further investigation in correlating the prevalence rates of disease and positive cultures of small animals on the one hand and veterinarians and kennel keepers on the other hand. This is essentially the same need that is felt in connection with studying the poultry problem, and disease among poultrymen and poultry dressers as compared with control groups from the general population.

**The Sick Patient.** In a general way, it may be said that the sick individual is important as a source in inverse proportion to the severity of his disease. Subclinical cases and mild diarrheas may be extremely important, especially when such persons are employed and continue to work as food handlers, nurses, etc. Occasional outbreaks present epidemiologic features suggesting contact transmission, being less surely or semi-explosive in development. Many small outbreaks in the literature concern a number of severe cases convincingly attributed to an associate with a mild, almost unnoticeable syndrome and later found to have a positive stool culture. Particular attention should be given to this kind of problem where groups of different susceptibility are concerned, as, for example, in the pediatric wards of hospitals. Children are unquestionably more susceptible to salmonellosis than adults, and newborn infants may be infected at the time of delivery. Such an infant may, of course, in turn serve as a source of a serious outbreak in the newborn ward. The nasal secretions of infants and children with salmonellosis are frequently positive and this suggests an additional means of transmission from sick patients to contacts.

**Carriers.** Ever since the importance of the carrier state in typhoid fever was

recognized, the air has resounded with the arguments of those who believe the carrier state to be of similar importance in other *Salmonella* infections (some say the total number of carriers (permanent) of all types is greater than the total number of typhoid carriers) and the rebuttals of those who believe that carriers are practically unknown in other *Salmonella* infections. Analysis of the available facts permits a few generalizations. This, it should be understood, is one area in which it is highly desirable to think separately of the paratyphoid organisms A, B, and C on the one hand and other *Salmonellae* on the other hand. In addition, incidentally, *S. choleraesuis* is unique in virtually never being found in healthy carriers.

In general, at least 2 to 4 per cent of the cases of paratyphoid fever may be expected to go on to chronic carrier status; that is, to excrete the organisms for more than one year. Thus, the carrier rate is probably at least as high as that in typhoid fever. In one outbreak among infants due to *S. paratyphi B*, one-third still had positive feces at six months. Other typical figures for the organism include 3 per cent at 6 months, 20 per cent at 6 months, 10 per cent at 3 months, 4 per cent or 5 per cent at 4 months. On the other hand, in *S. typhimurium* and probably in most *Salmonella* infections in which acute diarrhea is the chief complaint permanent carriers are relatively rare. It must be recalled, however, that other *Salmonella* infections are far commoner than the so-called paratyphoid fevers, and some people believe that as many as *one quarter of all permanent carriers are carriers of Salmonellae other than the paratyphoid*.

However, it is probably true for the paratyphoid as well as other *Salmonella* infections that the subclinical case and the convalescent carrier is numerically a more important source of infection than the permanent carrier. Salmonellosis can spread through a population in groups of clinical and subclinical cases, connected by transitory carriers.

There is some evidence that infants and children are more frequently carriers of *Salmonella* than adults and there is good evidence that infants carry the organisms on the average for a longer period of time. For example, following one *S. bovis-morbificans* outbreak, 60 per cent were positive after one month, 35 per cent after two months, and 2 per cent for longer than three months. All who carried longer than six weeks were under one year of age.

**Natural Distribution of *Salmonella* Types.** The bacteriology of the genus *Salmonella* is probably better understood than that of almost any other group of bacteria. This was not true a generation ago, and the validity of many early reports in the literature is seriously impaired by inevitable doubt as to what member of the genus was being discussed. The Kauffmann-White Schema, worked out in its final form about 10 years ago, is universally accepted. Biochemical analysis and analysis by means of somatic and flagellar antigens has been carried to a high degree of refinement. These advances, far from complicating the bacteriology of the *Salmonella* group, have rendered it simple and highly accurate. Experience, however, and well-trained technicians are indispensable in analytic procedures. Problems of species identification can be referred for final arbitration to a number of regional, national and international *Salmonella* centers.

The uses of antigenic analysis are varied, remarkable and sometimes ambiguous and controversial. For example, in the earlier days, it was believed that a fairly sharp correlation could be made between sero-types of *Salmonella* on the one hand,



and natural host on the other hand. Thus, there grew up the belief that some *Salmonellae* were predominantly animal types and others were predominantly human types with a few intermediate types of little, if any, host specificity. The typhoid bacillus represented one extreme of so-called adaptation to the human host and typhimurium was a favorite example of lack of host specificity. Continued effort has been made to assign each new sero-type a place on the spectrum extending between these two extremes. In addition to implications concerning the origin and host of sero-types, correlations were attempted between sero-type and various clinical pictures. The difficulties of these tasks proved so great that about 10 years ago a school of workers developed who gave up practically all such efforts and acknowledged that in essence, practically any *Salmonella* other than the typhoid bacillus and *S. pullorum* can exist in almost any animal species and, further, that it can cause various clinical syndromes.

However, with the improvements exemplified by the arrival on the scene of the Kauffmann-White Schema, it has gradually become clearer which correlations between sero-types, clinical picture and host range are valid, and which ones are not. It is now possible to outline, at least tentatively, the predominant patterns of distribution in nature by sero-type and the predominant clinical pictures by sero-types without going back to the older sharp division between animal and human sources.

Recent work has resulted in the following changes of some traditional concepts. Omitting typhoid from the discussion, the paratyphoid B can be said to be only *relatively* specific for humans; that is, to a much less degree than was formerly believed. For example, in the experience of Edwards and others (1948), *S. paratyphi B* was proportionately 25 times commoner in human sources than in animal sources. Nevertheless, it is important to notice that it was reported from five of the six nonhuman animal groups in this study. A refinement in identification methods indicates that tartrate negative *S. paratyphi B* is limited to human sources and is usually associated with an enteric fever syndrome. The tartrate positive variant is found in man and other animals and causes an acute gastroenteritis as its usual clinical manifestation. *S. paratyphi A* and *C* have been reported on extremely rare occasions in animals and appear to be primarily parasites of man.

As for the so-called "other *Salmonellae*," the animal adapted types, the investigations of the past decade have shown that the distribution in host species for practically all of these sero-types is far wider than was suspected previously. In general, a list of the 10 commonest sero-types isolated from animals will be practically identical with a list of the 10 organisms most frequently isolated from human sources in the same region. For the bulk of these organisms then, present evidence indicates that they are all relatively widespread in animal species and man; that any host specificity is relative and may appear largely as a result of selection of the sources of the strains isolated and identified.

Knowledge of the distribution of *Salmonella* types, both as to their frequency as the cause of human infections (Felsenfeld and Young, 1949) and as to their host range, is fragmentary. In the United States it has been derived from several different sources, each of which is selective in the material collected for study. The largest series of observations have come from the *Salmonella* diagnostic centers, such as that of Seligman and others (1946) in New York and Edwards and others (1948) in Lexington, Kentucky. Cultures are sent to these centers for typing and classifica-

on. Accordingly, it may be presumed that the cultures received would represent to an unusual degree the more severe clinical problems, the unusual sero-types and the geographic areas determined by the location of the laboratories and medical centers using this service.

When the information is derived from the experience of hospitals, it is again weighted by the more severe clinical cases and there is little precise information available regarding the population from which patients are drawn.

A third source of information is random and miscellaneous reports in medical and veterinary literature of the recovery and identification of *Salmonella* strains from human cases, market meat, canned milk and other foods, and from outbreaks of acute gastroenteritis. Because of this diversity and fragmentary character of available information it is difficult, if not impossible, to obtain an unbiased and comprehensive view of host relationships and distributions of *Salmonella* sero-types. Such a view can only be obtained by intensive field studies, conducted in a limited locality, as, for example, the one recently conducted in Hidalgo County, Texas. Here an attempt was made to systematically examine the human population for the presence of *Salmonella* types and to correlate these findings with the occurrence of diarrheal disease on the one hand and association with various domestic animals on the other. More such studies are needed before valid generalizations can be drawn.

**Clinical Manifestations.** In general, *Salmonellae* cause three types of diseases in individuals. They are best designated enteric fever, septicemia with or without focal manifestations, and gastroenteritis. A fourth category is the subclinical or asymptomatic infection.

It may be difficult to decide whether to call some cases enteric fever or severe gastroenteritis. Moreover, one form may merge into or be followed (with an interval of remission) by one of the other forms. Thus, for example, *S. paratyphi B* infections may be ushered in by an acute gastroenteritis followed by a quiescent interval of about one week and then develop into typical enteric fever; the Germans refer to the initial stage as *Vorkrankheit*.

The picture of paratyphoid enteric fever is essentially that of typhoid, though usually mild. The course is that of a septic fever with termination by lysis. Malaise, headache, arthralgia, are predominant manifestations. Rose spots may occur. There are usually no notable gastro-intestinal signs or symptoms but ulceration of the bowel may occur. The disease typically lasts two to three weeks and the case fatality rate is low.

Septicemia without focal manifestations is probably much more frequent in all salmonellosis, including enteric fever, gastroenteritis and subclinical cases than is often realized. For example, a goodly proportion of children in general hospitals with fever lasting a day or two and without other serious signs may show a transitory *Salmonella* bacteremia.

The septicemia of more clinical significance is that eventuating in such focal pathology as meningitis, pneumonia, arthritis, pyelonephritis, subcutaneous abscesses, etc. The case fatality rate is frequently high.

Acute gastroenteritis is the clinical picture commonly associated with so-called "food poisoning." The predominant symptoms are nausea, vomiting, diarrhea, abdominal cramps and headache. This condition usually lasts a few days with spontaneous recovery the rule.



*Salmonella* infection may be associated with chronic or recurrent diarrheas, but such evidence is very meager; so meager that coincidental rather than a causal relationship is suggested.

A special category of clinical salmonellosis that deserves mention includes those focal manifestations mimicking acute surgical emergencies. They occur rarely, but may be the occasion for serious therapeutic error as when unnecessary appendectomy or cholecystectomy is performed.

**Pathogenesis.** Very little is known of the pathogenesis and not much more of the pathology of salmonellosis. This much seems certain. It represents not an intoxication by preformed toxins in ingested material as was formerly thought, but a real infection which varies in degree and course according to host factors and parasite factors. Of these, the size of the initial dose seems to be one of the most important. The portal of entry appears to be the intestinal tract with lymphatic invasion. It is a fact that in one autopsy series on adults dying from various causes, *Salmonellae* were found in 16 per cent of the mesenteric lymph nodes. On the other hand, a high occurrence of positive cultures from the tonsils of children has suggested to some workers that an additional portal of entry may be the lymphatics of the pharynx. In any event, what happens following invasion of the intestinal lymphatics determines the clinical picture. In acute gastroenteritis presumably such invasion is itself minimal and limited. The intestine reacts violently by hypersecretion and hypermotility and in a matter of hours or days, the organisms are eliminated from the body. Alternatively, if invasion of the lymphatics is followed by invasion of the blood stream, positive blood cultures may result, but that does not necessarily mean that septicemic complications are inevitable. Positive blood cultures, even with an organism such as choleraesuis, which is undoubtedly more invasive and pathogenic than most other sero-types, are not always associated with severe clinical manifestations. In paratyphoid enteric fever, the pathogenesis and pathology are similar to that of typhoid fever.

**Incubation Period.** A considerable number of food-borne outbreaks of salmonellosis are on record in which it has been possible to determine the period elapsed between the time at which the group was exposed upon a common occasion or to a common foodstuff, and the onset of symptoms in the individuals affected. The minimum incubation period in these outbreaks has seldom been less than six hours, and the maximum period seldom more than 48 hours. In Feig's (1950) analysis, based upon 45 outbreaks, the mean was 18 hours, the interquartile range varied between 10 and 28 hours. The length of the incubation period in an outbreak of food poisoning frequently serves to distinguish those which are due to *Salmonella* contamination of the food and those which are due to staphylococcus or chemical poisons (see page 805).

**Frequency in Food Outbreaks.** In a recent analysis of outbreaks reported to the U. S. Public Health Service, 1945 to 1947, Feig (1950) found that in 476 outbreaks of gastroenteric disease in which effort was made to obtain the bacterial cause, 368 were attributed to staphylococci, 72 to *Salmonellae* and the rest to other organisms. In 42 of the outbreaks due to *Salmonellae* the species involved were determined. Sixteen were due to *S. typhimurium*; seven to *S. newport*; four to *S. oranienburg*, four to *S. montevideo*, two to *S. aniegar*, two to *S. newington*; and one

ach to *S. copenhagen*, *S. derby*, *S. choleraesuis*, *S. enteritidis*, *S. thompson*, *S. manhattan*, *S. panama*. In 56 of these outbreaks in which the contaminated vehicle had been determined by epidemiological investigation, the following frequencies were found: meat or meat products, 15; poultry, 10; bakery products, 8; potato salad, 1; eggs, 4; fish, 2; vegetables, 7; water, none; milk and milk products, 8; shellfish, 1.

**Control.** Basically, the rationale of control depends on how one visualizes the sources and spread of *Salmonella* organisms. When the animal reservoir of *Salmonellae* seemed all important and somewhat delimited, there was hope of blocking the natural sources. As it was realized how vast that animal reservoir is for practically all *Salmonella* types, that hope has diminished. In so far as the human carrier, especially the long-term carrier, is of importance, one may hope to break the chain of infection at that point. Elaborate precautions are legislated and sometimes enforced concerning the permanent carrier of paratyphoid organisms. At least one state has recently included in its provisions concerning occupational restriction, free cholecystectomy, etc., not only of paratyphoid carriers, but permanent carriers of any *Salmonella* sero-type. Routine examination of food handlers to detect carriers is being abandoned, for reasons of economy and common sense, almost everywhere. If human disease is propagated by direct contact between infected individuals and susceptible hosts, the clinical cases may be connected by chains of *temporary* convalescent or healthy carriers, which chains may sometimes be fairly long and continuous. The elimination of such contact is practically impossible to achieve except by the slow process of education in personal hygiene and improvement in the standard of living.

Granted that *Salmonellae* are widely distributed throughout the animal world, and granted that fundamentally man becomes infected because he ingests a material containing the organisms in sufficient numbers to establish infection, it is obvious that the lines of transmission must converge on the individual consumer of the contaminated material. Theoretically then, the place to attack with greatest hope of success is where the greatest convergence occurs, i.e., immediately before consumption of the material. That focuses attention on cooking, and traditionally thorough cooking has been advocated as a means of avoiding *Salmonella* infection. One trouble with this is that thorough cooking is very seldom described or defined. It is really quite simple. Thorough cooking means sufficiently high temperature to kill disease-causing organisms which might be present. Practically, this means cooking food in small containers or cooking meat in small pieces or cooking it hot enough or long enough to heat the center of the dish or the center of the piece. On a practical level, one cannot overemphasize the importance of this obvious item. Routine use of the meat thermometer, especially in restaurants and institutions where food is prepared in large quantities, is of real value. Cooks could be educated to read the death warrant of *Salmonellae* in the middle of any dish by the use of this inexpensive utensil.

Efforts to control *Salmonella* infection further back along the anus to mouth pathway are represented by the activities of the food inspectors and the veterinary problems involved. Routine antemortem inspection of food animals in most parts of this country has reached a sufficiently high level to eliminate a large number of animals sick with salmonellosis. But if it be granted that widespread invasion



of the tissues and organs of animals generally does not occur in the absence of clinical disease, then it follows that organisms are getting into food from slaughter houses and elsewhere from intestinal contamination. Some animals are fecal carriers and these cannot be detected by inspection.

A foodstuff currently of considerable importance in the *Salmonella* problem is egg powder. It is an excellent food and yet a very large proportion is contaminated with *Salmonellae*. Control of human disease from this source should be relatively simple. The basic fact is that while powdered egg is frequently contaminated, it is seldom heavily contaminated. The control implication is: teach the cook not to let reconstituted mixtures stand at room temperatures for very long, and secondly teach him to cook them thoroughly. The other point of attack is in the preparation of the powders themselves. Some form of pasteurization has been suggested and should be feasible. Counts can be significantly lowered by using clean eggs and by rapid reduction of the temperature of the egg meats after cracking.

The control of the water and milk supply need merely be mentioned. These two mechanisms for the mass dissemination of infectious agents are well protected in this country today and are no longer important sources of salmonellosis, if indeed they ever were.

The problem of salmonellosis spread by contact between an infected individual and a susceptible recipient is not essentially different from any other contact-spread disease. It is a matter of even greater attention being paid to personal hygiene and of increasing education in the population at large as to the importance of their personal sanitation. This is particularly important to emphasize in relation to those individuals who take care of sick patients. Nurses, physicians, ward attendants in hospitals have a particularly good opportunity to acquire contamination on their hands and spread this material to other individuals. Close attention to accepted handwashing technics will accomplish a great deal in the prevention of this type of transmission.

Community activities directed toward the control of arthropods in the name of prevention of salmonellosis are not justified on the basis of present evidence. As indicated above, many insects can spread these organisms effectively, but present indications are that they play a relatively minor role in the actual dissemination of the disease as it appears today. The same comment might be made with regard to rats and mice. These statements should not be taken as indicative of any lack of desire to eliminate these arthropod and rodent pests. They are simply to emphasize that there are other, and far more cogent reasons for the elimination of these nuisances than is their proven relationship to salmonellosis.

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## SHIGELLOSIS

*(Bacillary Dysentery)*

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The history of dysentery goes back to the remotest period accessible to historical inquiry. Dysentery is frequently mentioned in Hippocratic collections along with diarrhea. Indeed, Hippocrates himself indicated in the most definite way the close relationship of the diseases to one another in an epidemic. These associated conditions have been known throughout medical history as common afflictions of mankind and causes of great morbidity in civilian and military populations. In the accounts of pestilence by medieval historians and chroniclers, dysentery is most frequently mentioned after plague and pestilential fever. As Zinsser puts it in his "Rats, Lice and History": "Soldiers have rarely won wars. They more often mop up after the barrage of epidemics. Typhus with its brothers and sisters—plague, cholera, typhoid, dysentery—has decided more campaigns than Caesar, Hannibal, Napoleon and all the inspector generals of history. The epidemics get the blame for defeat, the generals get the credit for victory."

In the American Civil War, the annual morbidity rate attributed to dysentery in the northern armies was 876 per 1,000 and the death rate 10.3 per 1,000; and the situation was equally bad or worse in the southern army. During World War I it was a major problem in all of the armies. In World War II with greatly improved measures of military sanitation it was still in many areas the cause of a high non-effective rate. It is particularly notable that even in the Navy, with its excellent sanitary system, epidemics of dysentery occurred on ships at sea and off shore at Leyte Bay (Weil, 1947) and in Tokyo Bay (Thompson and White, 1946). In civil populations its relative importance as a cause of morbidity and mortality can only be surmised, since bacillary dysentery accounts for an indefinite proportion of the cases and deaths recorded under such diagnoses as diarrhea, summer diarrhea, diarrhea and enteritis, and dysentery unclassified. There can be no question, however, but that it has been one of the most important causes of death in infants and old people, among inmates of institutions, and among groups of the population living under primitive conditions. As enteric infections decreased in the United States, the incidence of diarrhea, dysentery and enteritis decreased at a slower rate than did typhoid.

The clinical distinction between dysentery and diarrhea has been maintained up to the present, though the difference is frequently one of severity rather than cause. In general, the term "dysentery" is applied to a febrile illness characterized by a sudden onset with abdominal pain and the passage of frequent stools containing blood and mucus accompanied by tenesmus. It may terminate either abruptly in death, within a few hours, or by gradual recovery, or rarely the disease may pass into a subacute or chronic state.



Toward the end of the nineteenth century, the clinical syndrome known as dysentery was found to have a dual etiology. It was established that one form of dysentery was due to amebae (*Entamoeba histolytica*). The other, and by far the commonest, form was found to have a bacterial etiology. In 1896, Shiga, studying an epidemic of dysentery in Japan, isolated the organism which now bears his name, and presented acceptable evidence of its etiological relationship. In 1900, Flexner, then a member of a commission sent out by the Johns Hopkins University to study the disease prevailing in the Philippine Islands, reported recovery from cases of dysentery of a bacillus closely resembling Shiga's organism. These observations were confirmed and extended by Strong and Musgrave working in Manila, by Krusé working in Germany and a succession of investigators. As additional nonmotile, Gram-negative rods were identified as having a causative relation to acute diarrheal diseases and their antigenic and biochemical structure was determined, it became apparent that there were several different species involved; all were included in the genus *Shigella*. Four principal groups, each composed of a number of sero-types have been recognized, viz., Group A *Shigella dysenteriae*, Group B *Shigella flexneri*, Group C *Shigella boydii* and Group D *Shigella sonnei* (Ewing, 1949).

**Diagnosis.** Since dysentery has a dual etiology, its differential diagnosis depends upon demonstration of the etiological agent. Moreover, there is a wide variation in the severity of clinical symptoms due to organisms of the *Shigella* group, ranging from fulminating attack of dysentery with fatal issue in a few days to a mild diarrhea, and diarrhea, in turn, merging with inapparent or subclinical infections. To designate this whole range of host reactions the term Shigellosis has recently come into use. Clinical criteria may provide a reasonably satisfactory working diagnosis for the treatment of an individual case, but a positive statement as to the etiology cannot be made on clinical grounds alone. Similarly, while the occurrence of cases of diarrhea and dysentery of sufficient severity to seek medical attention is usually an index of the prevalence of shigellosis in a community, an adequate idea of the distribution of these organisms in a population can be obtained only by bacteriological examinations made on a representative sample of persons who may or may not have recently been suffering from an attack of diarrheal disease. Prevalence rates are, therefore, dependent upon two principal factors: first, upon the care and thoroughness with which the bacteriological examinations are carried out, and second, on the selection of the groups that are examined, i.e., whether they be drawn from hospital and medical sources or whether they be drawn from the population at large.

Laboratory diagnosis by serological testing of the patient's serum for specific agglutinins is not a satisfactory procedure. Agglutinins are produced late in the disease and only in low titers. Moreover, the serum must be tested against a large number of type strains. The use of mixed strain suspensions reduces the chances of detecting antibodies present in low titers. The only satisfactory laboratory procedure is the fecal culture and isolation of the etiologic organism.

Two methods of obtaining and handling fecal specimens have been usually employed. The first is the collection of a small amount in a glass bottle half filled with preserving fluid. A preservative commonly used is 25 per cent glycerine in

normal saline buffered with disodium phosphate to give a pH of 7.4 to 7.5 after autoclave sterilization. The second method is to culture directly by rectal swab technique (Hardy and Watt, 1950). The development and use of highly selective culture media has markedly simplified the isolation of intestinal pathogens. In 1935, Zeifson developed a selective culture medium (desoxycholate citrate agar) which permitted for the first time large scale field studies, which have been so important in adding to our knowledge. Later, the *Shigella*-*Salmonella* (Difco), usually referred to as the SS agar, was found to be even more useful. After 18 to 24 hours of incubation at 37° C on selective media, suspicious colonies are picked to Russell's double or Krumwiede's triple sugar or Kligler's iron agar. The differential tube medium is examined after 16 to 20 hours incubation at 37° C. Final identification of the pure and species classification culture is established by cultural reactions and agglutinability with standardized poly- and monovalent typing sera. When carefully carried through by well-trained bacteriologists, dysentery bacilli can be recovered and identified from at least 70 per cent of infected persons. The failure to isolate *Shigella* from stools in acute diarrhea is more frequently related to the quality of laboratory work than it is to the actual presence of these organisms in the intestinal canal of the patient studied.

**Frequency of Shigellosis.** Investigations of shigellosis in the United States have, in general, followed two main patterns. Earlier studies began with the clinical case of *acute diarrheal disease* in hospitals and clinics. Bacteriological and clinical investigations were directed toward the determination of the etiology of individual cases, and of outbreaks in which the symptoms indicated an etiological entity. These diagnostic studies, taken as a whole, record a wide variation in the frequency with which *Shigellae* have been recovered from cases of illness. On the other hand, there is a remarkable similarity between the results of a few studies, particularly when one considers the tremendous difference in the methods available to each of the investigators. The common denominator of these studies appears to have been active participation by all the responsible personnel and meticulous efforts to assure the validity of a "negative" finding.

Flexner and Holt (1903) in eastern cities; TenBroeck and Norbury (1916) in Boston; Davison (1920) in Baltimore and Birmingham; McGinnis and others (1936) in Virginia; Cooper and others (1939); and Hardy and Watt (1948) in New Mexico and Georgia all showed that the majority of clinical illnesses classed as acute diarrhea were associated with the *Shigella* group of organisms. Since 1940, other areas have had similar investigations with similar results. It has thus been amply demonstrated that the principal agent found in severe acute diarrheal diseases is a member of the *Shigella* group. The qualifying adjective "severe" is extremely important to this generalization. (In this context, "severe" includes patients sufficiently ill to cause them to seek medical attention or, in the absence of good medical care, sufficiently ill to cause loss of time from work or play or an actual danger to life.) As living conditions have changed, statements of this nature must be more and more qualified according to regional conditions. A diarrheal disorder which would cause a great deal of concern to a mother or a pediatrician living in a modern city would be considered of relatively little significance by similar individuals living in an area where morbidity and mortality rates have not shown significant change during the past 50 years. This point must be kept firmly in mind when evaluating



statements about the acute diarrheal diseases and the frequency with which different causative agents are encountered.

The second general approach has been to study the frequency of *Shigella* infections in the general population. These studies have agreed with the clinical investigations mentioned above wherever it was possible to make direct comparisons. They have shown that where acute diarrheal diseases are a major health problem the *Shigella* group of organisms is associated with the majority of the severer illnesses.

**Carriers.** Further, they have shown that these illnesses constitute only a small number of the total infected individuals. It has been repeatedly demonstrated that for every person currently ill with *Shigella* infection, 8 to 10 other individuals in the immediate environment can be shown to have positive stool cultures but showing no symptoms of disease. This ratio of cases to subclinical infections varies considerably with age. In the very young it is rare for an individual to become infected without the development of clinical symptoms. As progressively older groups are considered, an increase is found in the frequency with which asymptomatic infections occur. One expects to find approximately five times as many subclinical infections per case in individuals over five years of age than is true in children under five.

A striking example of the frequency with which *Shigella* infection may go undetected is in a study carried out in New Mexico and Georgia. Three hundred and eighty individuals were found positive on surveys of the general population. These individuals had been examined simply because they lived in a chosen area and not because of any previous experience with diarrheal disease. Careful history revealed that only two of these people had been sufficiently ill to cause them to seek medical attention. Two hundred and thirty-nine could recall no illness at all. Thus, less than 1.0 per cent could have been detected by usual reporting methods through the practicing physician. Even if there were a complete record of all illnesses, approximately two-thirds of the infections would have been unrecognized since there was no associated illness.

There have been several studies of the duration of the carrier state in convalescence from a clinical or subclinical infection. The observations of Watt and others (1942) are pertinent in this connection. Serial stool examinations were made during the illness and at weekly intervals after recovery until three negatives had been obtained on a series of patients. Of 103 found positive during the illness, 82 were still positive at the time of clinical recovery. One week after recovery, 73 were still positive; the number gradually decreased until only seven were positive (or about 10 per cent of the original number) at the end of 10 weeks or more. Upon the basis of this experience and the observations of others, it may be stated that the average duration of the carrier state is about one month, but the organisms may persist in the intestinal tract of some individuals for several months. In a series of cases studied by Perry in 1925, 7 per cent of the patients harbored Flexner one year after their primary illness. Thus, occasional individuals may harbor *Shigella* for long periods of time, serving to carry the infection over in a community from one year to the next.

**Resistance.** Outside the human body *Shigella* organisms are extremely sensitive to environmental conditions and tend to die off rapidly. Even in feces they survive only for a short time. For this reason it is necessary to make bacteriological cul-

res as soon as possible after the specimen has been passed, unless a preservative has been added. Exposed to sunlight and drying the organisms die in a few minutes. They are easily destroyed by heat and chemical disinfectants. The importance of three factors must be recognized if any understanding of the epidemiology of shigellosis is to be achieved, viz., (1) the relative mildness of most of the clinical manifestations; (2) the relative frequency of asymptomatic infections; and (3) the relatively long duration of the carrier state.

**Types.** The original type discovered by Shiga produced a severe clinical illness and was different from the remainder of the group in that it elaborated a soluble exotoxin. This organism has been conspicuous for its absence in the United States during recent years in spite of the fact that it constituted a large proportion of the cases seen by early investigators (circa 1900). In addition to this decrease in the United States, there is an indication that the same type of change is taking place on a world-wide basis. They have been encountered so infrequently since the development of the selective culture media that no recent epidemiological studies have been made on shigellosis caused by *S. shiga*. Therefore, the distributions which have been observed pertain only to the other strains, Flexner, Sonne and Boyd. In general, epidemiological concepts are applicable to the group as a whole.

**Prevalence.** A tremendous variance exists in the frequency with which *Shigellae* can be found in the general population. In a recent study in New York City, from over 5,000 cultures in a normal population group, only two isolations of *Shigella* were made. In contrast, during a comparable period of time and using similar methods, some population groups in south Texas, south Georgia, New Mexico and California have been shown to have as high as 20 per cent of the individuals studied infected at one time. These rates are extremes, but illustrate the kind of variation which does take place within a single country.

An even more important variation is that which takes place within a much smaller geographical unit. Studies made of representative samples of the general population of a number of areas have shown that those families with good housing and those in the higher economic brackets show rates of *Shigella* prevalence not unlike those found in New York City; this in spite of the fact that only a few blocks away in another section of the same town prevalence rates of 15 to 20 per cent may be found.

**Season.** The high rates mentioned above usually occur in the general population during the spring, summer, or fall months, depending upon the section of the country. In general, the colder the winter months the later in the summer do high rates appear. In those section of the south where the winters are mild, a rise in *Shigella* prevalence usually occurs in April, May and June. In many of these areas this is followed by a sharp drop in prevalence in the summer months to be followed by a secondary rise in the fall. In areas where the seasons are more sharply differentiated, it is much more common to find a seasonal peak in mid to late summer. Prevalence studies have not been made in sufficient detail in tropical countries to permit a general description of variation in those areas. Such studies carried out under tropical conditions would be an important addition to our knowledge.

**Age.** *Shigella* infection shows a relatively characteristic age distribution in the general population of areas with a moderate to high endemic occurrence. Prevalence rates are low in the first six months of life, rising during the next six months



and reaching a level which remains relatively constant for several years. Beginning about the fourth year, there is a general decline in prevalence rates, reaching a second level about age 15. There are relatively unimportant variations after this time.

The age distribution of *clinical disease* produced by *Shigella* has a somewhat different pattern. It is relatively infrequent in the first few months of life, has its greatest frequency between 9 and 18 months and thereafter falls rapidly to a much lower level. Attack rates in young children are frequently 10 times those in adults. It is difficult to determine how much of this difference in age-specific attack rate is due to the greater resistance of the older individual to gastro-intestinal disturbances and how much is due to specific immunity acquired as a result of infection in early life. A study of household attack rates in New Mexico, Georgia and New York indicate that at least some of this difference is due to specific immunity. A comparison of the household attack rates in the Spanish-Americans and Indians (in general, a low income group) with the Anglo-American households (a significantly higher income group) showed that approximately twice as many older people developed clinical illness in the Anglo-Americans than was true in the Latin-Americans. A similar difference was observed between white and colored families in Georgia. White and colored groups in New York City, however, did not show such a difference and the attack rates were more nearly comparable to the better income groups in the south and west. These differences are best explained by the fact that in the south and in the west the lower income groups have a significantly greater amount of *Shigella* infections at all times than do the more fortunate residents of the area. In New York City, however, the prevalence of *Shigella* infections is extremely low and the opportunity to acquire infection is unlikely to occur even in the poorest households.

**Transmission.** *Shigellae* are spread naturally in a number of ways and the importance of these mechanisms of spread varies in different localities and times, either actually or relatively. The maintenance of a high level of *Shigella* infection in a group depends upon the more or less direct transfer of human feces containing *Shigella* from one individual to another. Therefore, any factor which tends to reduce the quantity of feces in circulation in a community will tend to reduce the amount of *Shigella* infection.

An illustration of this principle is readily apparent with respect to flies. Recent studies (Watt and Lindsay, 1948) have established that in *particular areas* fly control on a community-wide basis does result in a significant reduction of *Shigella* infection. However, an appreciable amount of shigellosis remained in these areas in spite of intensive efforts at fly control with chemical insecticides. A community with open privies, a large fly population and inadequately screened houses will present many opportunities for flies to become contaminated and to easily transport the infectious material to susceptible individuals. On the other hand, in a community in which human excrement is not left open to flies or in which the individuals are protected from flies by screening and the use of various household insecticides, flies can play only a minor role in the transmission of infectious material, since on the one hand they would not have access to such material, and on the other hand, they would not have access to the susceptible individuals necessary for a continuous chain of transmission.

Shigellosis has been shown to spread effectively in institutions, military groups and in some communities under circumstances which eliminated all of the avenues of dissemination except direct person-to-person transfer of fecal material. In most communities in which any one mechanism of spread has been reduced in importance, there has been a concomitant improvement in the general standard of living. This, in turn, results in important reductions in the ability of any other mechanism to function.

**Prevention and Control.** The reduction of shigellosis to the point of extinction is possible. This has been amply demonstrated by the virtual disappearance of these organisms from cities and rural areas which are modern in a sanitary sense. There remain, however, tremendous areas of the world and significantly large portions of the United States in which these modern developments have not yet occurred. Furthermore, unless there is a spectacular change in the rate of improvement, shigellosis will be a major problem in these areas for many years to come. In the meantime, however, it is important to use available resources in such a way as to obtain the greatest amount of control for the time and effort expended.

The preventive measures which can be expected to be valuable may be divided, for administrative purposes, into two major groups: (1) those which can and should be taken by individuals and (2) those which can be most effectively applied by community or group action.

The efficacy of *individual control measures* is directly related to the degree of understanding of the problem which has been achieved by the individual and the opportunity for carrying out the necessary precautions. Personal hygiene is a matter of no concern to an infant, nor is it of any concern to an adult who has lived his whole life in an environment lacking in basic sanitary facilities. An adult who has never seen a flush toilet can no more be expected to automatically use and maintain such equipment than an infant can be expected to use and maintain the same type of equipment. The infant learns by patient teaching on the part of the parent and this example must be followed in dealing with any population group suddenly afforded modern sanitary facilities. Handwashing to remove infectious material and thus prevent spread to others is another habit which is acquired through training. Further, these habits are practiced in inverse ratio to the difficulty involved in carrying out a particular action. Hands will be washed frequently and effectively only if running water is readily available. Therefore, individual preventive measures for diseases of this nature, although they must be carried out by each person, are dependent in part upon the effective installation of community utilities.

The *community measures* which are of greatest importance are the provision of a safe water supply made easily available to all members of the community. In thinking about a water supply to be provided to a community, it is customary to think of it as a foodstuff to be consumed by man; it can thereby act as a vehicle of dissemination of an infectious agent. Another role a water supply can play is frequently overlooked; it can also dilute and wash away infectious material. One can visualize a situation in which a lightly contaminated water supply could actually more than offset the cases of disease it spreads in its role as a foodstuff by the number of cases it prevented through serving as a cleansing agent and a remover of human wastes in a sanitary manner.

Safe removal of human excrement, preferably by a water-borne sewerage system,



is a second important factor. A third is the protection of foodstuffs distributed on a community-wide basis. This would include the provision of a safe milk supply, proper handling of foodstuffs in public eating places, and similar protective devices. The fourth community activity is the adequate removal and disposal of human and industrial wastes which constitute an important source of fly production. This latter, of course, is a combination of community and individual activity, since disposal and collection can best be done on a large scale and the care of individual properties must be the responsibility of an individual household.

It would seem that it would be unnecessary to add that all of these services must be made available at a cost which can be met by the poorest member of any community. Yet all too frequently, municipal ordinances require sewer connections for all residents but no sewer lines are available for house connections. In other cases the sewer lines may be present but the cost of making such a connection is prohibitive because of the low income of some of the people served. It is in situations of this sort that shigellosis is still taking a major toll of life and health in this country today. Problems of this sort can and have been solved in communities on their own initiative whenever a sense of local responsibility has been developed on a community-wide basis. Furthermore, experience demonstrates conclusively that with an improved standard of living, and the opportunity and desire on the part of the population to devote some attention to personal and community hygiene, shigellosis cannot maintain its position as an important cause of human disease.

In the event of an epidemic in an institutional, military or civilian community, individuals with a diarrheal disorder should be placed under medical supervision as rapidly as they can be discovered. Broad spectrum antibiotics are effective in treatment and significantly shorten the carrier state. Some sulfonamide preparations are also useful. Institutional outbreaks can be controlled by effective use of one or more of these drugs. Except under unusual circumstances it is not worth while to try to discover carriers. If the outbreak is explosive in character, suggesting infection of a group of individuals by a common medium, investigation of food, water and milk supplies should be immediately instituted. At the same time, every effort should be made to reduce the opportunities for person-to-person propagation of fecal material by direct or indirect contact through appropriate sanitary and hygienic measures.

The possibility of using mixed bacterial vaccines has been under investigation for many years. None of the preparations so far produced has proved effective in development of active immunity when treated under field conditions. There is still much that remains unknown about the nature of the immunity to *Shigella* infection.

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## DISEASES AND INFECTIONS DUE TO INTESTINAL PROTOZOA

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## AMEBIASIS

(Amebic Dysentery)

Amebiasis is a chronic infection of which the so-called classical amebic dysentery is only one clinical entity. Amebiasis is usually visualized as a tropical infection but it is interesting to note that it was first discovered by Losch, in 1875, in a patient in St. Petersburg (Leningrad), U.S.S.R., who had just come from Archangel, even farther north. The infection is now known to occur widely in both the north and south temperate zones. In general, however, it is more common and clinical amebiasis more frequent in the sub-tropics and tropics.

**Host Reaction.** The causative organism is *Entamoeba histolytica* \* which lives primarily in the colon. Hegner found evidence in monkeys that they could colonize and multiply in the lumen, i.e., in the fecal content of the colon. Craig, on the other hand, was convinced that the infection does not persist without some tissue invasion. In support of this postulate he summarizes his own observations and the reports of Johnson, Faust, and others, and even some of Hegner's experiments, which demonstrate that small, almost pinpoint lesions, and even extensive invasions of the tissues occur in the colon of both man and experimental animals in the absence of any demonstrable clinical evidence of such pathology. It is implied that a more extensive and adequate search of the post-mortem colon could hardly fail to demonstrate, at least, microscopic lesions in those who harbor the organism. Craig states that over half of the so-called "carriers" have histories of the symptoms of amebiasis.

\* The spelling of *Endamoeba* for the generic name which has been so commonly used in American medical literature is an error due to confusion with *Endamoeba blattae* (Butschli, 1878) Leidy, 1879. *Entamoeba histolytica* and *Endamoeba blattae* are not in the same genus. The similarity in the spelling of these two generic names is unfortunate. For details see Kirby (J. Parasitol. 31:177, 1945) and Stoll (Opinion 312, Internation. Comm. on Zool. Nomenclature, Am. J. Trop. Med. Hyg., 4:376, 1955).



Sapero, in 1939, reported an objective study in which histories were taken and physical examinations were done on 450 apparently healthy Navy personnel in Panama, while fecal examinations were made independently on the same group of men. Of the 106 who were found to harbor *E. histolytica*, 43 per cent had symptoms suggestive of amebiasis whereas only 23 per cent of those in which *E. histolytica* was not found presented such symptoms. Abdominal distress and demonstrated localized abdominal tenderness were most frequently found. Localization in many cases suggested chronic or subacute appendicitis, which is a symptom-complex commonly developed in both chronic and acute amebiasis.\* However, Sapero's findings also demonstrate that many individuals harbor the infection without sufficient ill effects to lead them to consult a physician. The infection may, and in many cases obviously does, follow an insidious course. Recurrent crops of minute lesions may produce no sign of illness, but extension in number and size of these lesions may produce ill defined abdominal distress and tenderness; still further extension of the lesions or perhaps delay in healing may produce the frankly chronic cases of amebiasis; and still further extensions of such lesions may produce the acute dysentery. Extra-intestinal extension of the lesions most commonly occurs in the liver and evidence is accumulating to indicate that this is more common than formerly appreciated.

Although there may be some tissue invasion in most, if not all, infections with *E. histolytica*, one should not lose sight of the fact that most infected individuals in the temperate zones and many in the tropics are unaware of their infections until apprised of the fact from routine survey examinations.

Since most infections appear to be asymptomatic or mildly pathogenic, much consideration has been given to how these differ from the comparatively few in the temperate zone or the somewhat larger portion in the tropics who obviously suffer from the disease. Various strains or races of this organism have been postulated and it is even suggested that *E. histolytica* may in reality be a complex of several almost indistinguishable species. Sapero and others (1942) reported that in their series of 283 cases in Panama the cyst fell into two distinct size categories, that in 57 per cent of the cases only the large race (11-12 $\mu$ ) were found, in 37 per cent only small race (7-9 $\mu$ ), and in only 6 per cent were both found. In the latter group the organisms seen fell distinctly into a bimodal distribution, suggesting double infections and not intermediate forms with large and small extremes. Furthermore, in a number of cases followed over several months from the period of illness through apparent convalescence and clinical remission, the parasites remained consistently of the same size throughout. In all these cases the large race was present exclusively. In most other studies there have been no references to the size of the organism but in the limited studies in which size has been determined only the large race has been found present in patients suffering from clinical amebiasis. A number of workers have shown that the large race taken from clinical cases of amebiasis become more readily established in laboratory animals and produce more extensive lesions than do the small race taken from asymptomatic individuals. Some evidence has been presented also which suggests that there may be two or more races or strains which differ antigenically one from the other, but these have not been correlated with

\* In the Chicago epidemic, surgical intervention in amebiasis simulating surgical conditions was associated with a 50 per cent mortality rate.

It cannot be unequivocally denied that the larger size and greater virulence result from the rapid transfer of *E. histolytica* through susceptible hosts or rapid development in a particularly susceptible host. Since the two races, if they are genetically distinct races, can be distinguished only on the basis of size and possibly by the critical use of experimental animals, it is generally considered impractical, if not presumptive, to attempt such distinction in routine examinations.

**Laboratory Diagnosis.** Those with extensive experience with amebiasis generally agree that fecal examination is the most satisfactory means of establishing a diagnosis of the amebic colitis or amebic dysentery. As many as 10 or more different stools over a period of two or more weeks may be required to demonstrate the parasite. Even with the aid of the good illustrations and classical descriptions in most of the readily available books on parasitology or laboratory methods, the recognition of these forms is not easy. Even the experienced technician may have difficulty in identifying them, and the isolated technician without opportunity for interchange with experienced personnel is frequently in difficulty and may fall into a pattern of chronic error. Thus, in the temperate zones where clinical amebiasis is not commonly seen, the laboratory may completely miss the few cases on which aid is sought. A number of cases, including some fatal cases, in the Chicago epidemic were not correctly diagnosed because of the omission of or inadequacy of laboratory examinations. Even more commonly the unsuspecting patient is committed to a course of treatment for amebiasis while the actual cause of his illness is not discovered because harmless amebae or even epithelial cells have been mistaken for *E. histolytica*. More than once a community has become concerned over a large number of "active cases of amebiasis" found by these means and several epidemics have been arrested" by correcting the laboratory diagnosis.

In view of the difficulty in maintaining adequately trained and experimental technicians in areas where amebiasis is not a major problem, a simple serological test employing standard technics would be a very useful tool. It has been suggested that a positive complement fixation might also distinguish between the case with colonic lesions and those who harbor the infection with little or no tissue invasion. There is, however, no evidence so far to support this hope. In spite of the intensified study of the serological aspects of amebiasis both at home and abroad in the past quarter of a century, there is still no clearly demonstrated use for such tests in colonic amebiasis. However, recent work by Terry and Bozicevich and by Massey and Brown (1950) have shown that the complement-fixation reaction may help resolve any suspicion of amebic hepatitis. This is significant because hepatic infections may persist in the absence of sufficient current colonic infection to produce cysts in the stools.

Two separate stages of the parasite are recognized:

**TROPHOZOITE.** The active *trophozoite* or vegetative stage is the biologically active stage. It is the stage which invades the tissues, feeds, and multiplies rapidly by binary fission. Once the infection is established, it is maintained and spread principally, if not exclusively, by the trophozoites through direct extension of established lesions and the initiation of new lesions by trophozoites discharged into the lumen of the colon or transported through the vascular network. However, the trophozoites are ill adapted for survival in the external environment or for passage through the acid condition of the stomach. While infections have been established



experimentally by massive feedings of fresh trophozoites there is nothing to suggest that they are in any way involved in the natural transmission of the disease.

**THE CYST.** The cyst has a heavy resistant wall and is well adapted for survival outside the body. There is no evidence that cysts are formed within the tissues, but rather they appear to be formed exclusively in the lumen of the colon from trophozoites discharged from the lesions. While it is not impossible that excystation may occur with the same host in which the cyst is formed, the available evidence suggests that this does not normally occur. There is some reason to believe that this stage requires exposure to external environmental conditions before it can excyst. It is probable that in addition to serving as a transfer stage, the cyst stage is part of the process of biological rejuvenation. The newly formed cyst is uninucleate, but two nuclear divisions while in the alimentary canal, result in the typical quadrinucleate cyst in the normal stool. Within a dysenteric, diarrheic, or otherwise loose or mushy stool any or all gradations may be found from the trophozoite, through pre-cysts to uninucleate, binucleate, trinucleate, or quadrinucleate cysts.

While the cysts of *E. histolytica* are provided with a protecting wall, they are really not prepared for survival under extremely adverse circumstances. They are not remotely comparable in this respect to such structures as the spores of fungi. They are quickly killed by drying or by the ultraviolet rays of the sun. Moisture is required for their survival and in water the length of time they will survive is limited by temperature. The infection is particularly common in the tropics and, therefore one may assume that conditions in the tropics enhance the transmission. Nevertheless, the cysts survive longer at freezing than at any higher temperature. One comparative study by Philpitschenko revealed a survival of three months at  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ); one month at  $0^{\circ}\text{C}$ ; 14-17 days at  $13^{\circ}\text{--}17^{\circ}\text{C}$ ; and only 24 to 48 hours at  $34^{\circ}\text{--}37^{\circ}\text{C}$ . The results reported by different workers under different conditions extend or decrease the time of survival in individual experiments but the relationship of decreasing survival time with increases in temperature above freezing is consistent. Survival up to one year at freezing has been reported but most workers have not succeeded in keeping them alive for more than a few weeks at room temperature ( $20^{\circ}\text{--}25^{\circ}\text{C}$ ) and above  $30^{\circ}\text{C}$  death is progressively more rapid with survival at  $45^{\circ}\text{C}$  being only a matter of minutes, and  $55^{\circ}\text{C}$  only a matter of seconds.

**Conditions of Transmission and Prevalence.** Thus, other things being equal, it would appear that the temperate zones and even the Arctic offer more favorable temperatures than the tropics for the survival and dissemination of the cyst of *E. histolytica*. Since this infection, like the bacterial enteritides is feces-borne, its dissemination requires an ample supply of undisposed feces from which man may directly or indirectly obtain his infection. A superficial study of scatology will quickly reveal that carelessness in fecal disposal increases rapidly as one moves within the United States from the northern states to the semi-tropical southern states. In many areas of the tropics there is essentially no attempt at sanitary disposal of feces. The rough correlation between unsanitary fecal disposal and the prevalence of amebic infection along broad geographical lines is further refined by considering the different types of populations within these various areas. Table 3-8 gives the results of a series of representative surveys of three different types of population in various parts of the United States. The prevalence of *E. histolytica* is low in college students, from New England (New Hampshire) to the deep south (New

Table 3-8. Comparison of the prevalence of *Entamoeba histolytica* in college students, rural populations and institutional populations in the United States

Area	Authority	Per Cent Positive
A. College Students		
New Orleans, Louisiana	Faust (1942)	8.3
" " "	Swartzwelder (1938)	3.1
Athens, Georgia	Byrd (1936)	5.2
Area, Kentucky	Headles and Cable (1942)	5.0
. Louis, Missouri	Tsuchiya and Jean (1940)	2.1
Philadelphia, Pennsylvania	Wenrich, Stabler and Arnett	4.1
Portsmouth, New Hampshire	Connell and French (1939)	1.4
B. Rural Populations		
Georgia	Seckinger (1936)	20.5
Tennessee	Meleney (1930)	17.3
"	Milam and Meleney (1931)	36.4
Virginia	Faust (1930)	20.0
Oklahoma	McMullen and Gray (1941)	10.0
New Mexico (Indian Reservation)	Spector and Hardy (1939)	25.9
Wyoming (Indian Children)	Owen, Honess and Simon (1934)	26.5
C. Institutional Groups		
New Orleans, La. (Orphanage)	Faust (1931)	55.5
Georgia (Mental Hospital)	Reardon (1941)	40.0
Maryland	Armaghan and Meeliary (1938)	13.6
(School for Feeble-minded)	Faust (1931)	13.8
New Jersey (Mental Hospital)		

Rearranged from Craig, 1944, table 3.

Orleans). On the other hand, it is just as high among the rural Indians of the arid west (New Mexico) and the far north (Wyoming) as it is among the rural population of southeastern United States. The highest infection rates are found in the unsanitary institutionalized groups (orphanages and mental hospitals). The gradient of infection in these three groups is roughly parallel to the gradient of unprotected fecal concentration near or in living quarters. There can be no question that the group of college students live under conditions where promiscuous defecation is not the rule. Although they are drawn from all groups of the population, the higher economic levels with better methods of fecal disposal, are much more commonly represented than are the lower economic groups. Among the lower economic groups in the rural population, small villages, and even in the cities of southern United States, toilet facilities, even when available, are relatively little used by children and indifferently used by adults. In every state in the southeastern United States there are many rural homes of the economically poorer groups without any structural provision for fecal disposal, and a significant number of public schools without such provision. The net result is fecal deposition at the site of immediate convenience and visual record of this is provided in the yards of many homes. In such an environment the indifference extends somewhat up the economic scale. One rural school board, drawn from the economically more stable elements of the population and whose members had children in the school, solemnly advised that they had carefully



considered constructing a sanitary privy and had concluded that the odor of concentrated feces not only would discourage its use but would constitute a greater nuisance than random defecation around the school house.

In an institution such as an orphanage even a nominal amount of violation of sanitary concepts may provide ample sources of fecal contamination in the midst of this congested population. Gross carelessness in fecal disposal which may take place in orphanages, and commonly does in mental institutions, provides the maximum concentration of feces in the midst of a population concentration.

Thus, the highest concentrations of unconfined feces appears to provide the opportunity of the greatest amount of transmission and the highest prevalence rate of amebiasis. Under these circumstances there is ample opportunity for direct contamination of hands, food and even drink. It is difficult under these circumstances to determine the exact vehicle of transmission. Nevertheless, less direct methods of contamination should be carefully considered for an understanding of the epidemiology of this infection.

**RAW VEGETABLES.** Wherever human feces is used as fertilizer in truck farming the resulting vegetables, particularly leafy vegetables such as lettuce, appear to constitute a possible source of infection. One should keep in mind, however, that much of the night soil is accumulated in storage jars before being applied to the crops and that many cysts are killed in this storage. Many more of the cysts which reach the leaves as the night soil is applied to the crops do not survive the subsequent period of growth before the crop is marketed. Thus, contamination of the vegetables with viable cysts is more likely to occur during harvesting or in subsequent handling even in an unsanitary kitchen. Among the Chinese, amebiasis is concentrated in family units and appears to be mainly associated, as in the southern United States with dooryard pollution by young children. Thus, any food, leafy vegetables included, may become contaminated where the sanitary conditions are generally poor.

**FOOD HANDLERS.** The infected food handler logically comes under suspicion with any enteric infection and can not be totally discounted in the transmission of amebiasis. Nevertheless, the available data are at least ambiguous. In the Chicago epidemic the food handlers, as well as other employees, in the incriminated hotel showed a high rate of infection. It is probable that they, as well as the guests, were the victims of the contaminated water and, while they may have contributed to the contamination of the water, there was nothing to suggest that they disseminated the infection through the handling of food. The gross contamination of the water in this situation may, of course, have masked any subtle role of the food handlers in the epidemic. It has been suggested that the familial distribution of the infection in the rural areas of southeastern United States may have resulted from the infected housewife in her role as a food handler. In view of the widespread fecal contamination in such areas nothing as subtle as this is needed to explain the familial distribution. Furthermore, both ascaris and hookworm have such familial distributions in these areas and neither could be transmitted directly from an infected individual through immediate food contamination since both require a protracted period of development in the soil. Schoenleber (1940) reported a 90 per cent reduction in both the colonization rate and the infection rate with *E. histolytica* as a result of treating infected food handlers, apparently also treating those in the general population who were infected, and enforcing improved personal hygiene and general sanitation in the handling of food.

mention is made of what other improvements may have been accomplished in general use of the available sanitary facilities. The results were truly remarkable and it is unfortunate that only those data are presented which seem to support his previous conviction that the infected food handlers were exclusively responsible for the transmission of the infection.

Sapero and Johnson considered the possible role of the infected food handlers in spreading the infection among naval personnel. In their series, officers and enlisted men served by infected food handlers actually had a lower infection rate than those served by noninfected food handlers. In neither group was the infection rate higher than that to be expected in the United States. It seems evident then that with good kitchen and mess practices, infected food handlers do not constitute any immediate source of infection.

**FLIES.** It has been amply demonstrated that flies and other insects are capable of carrying and discharging viable cysts. Viable cysts have been found in the vomitus of flies and in the feces of both flies and cockroaches as much as two days after they were ingested. It is commonly assumed, therefore, that flies can and do transmit the infection in nature. The prevalence of flies in unsanitary areas, particularly in the tropics, is often cited as supporting the theory of fly transmission. Again, as with the postulate with respect to infected food handlers, there seems to be a significant regard for the more direct and immediate contamination of food and drink. Craig reported an outbreak of amebiasis in 1916 among troops serving along the Mexican border at El Paso, Texas, coincidental with an increased fly population. It is possible that flies played a role in the transmission of the infection but it is not clearly demonstrated. The fact that flies and the disease rate followed the same time curve does not allow for the usually extended incubation period in amebiasis.

Certainly in many areas flies, though abundant, fail to transmit the infection. Thus, along the Mediterranean coast of North Africa the high temperature and the dry winds destroy cysts if they do not reach a moist medium quickly. Sanitation is conspicuously lacking and flies are abundant with ample opportunity for traffic between feces and food. If flies play an important role in the transmission of this infection it is difficult to see why the amebic dysentery of tropical Africa should give way in much of North Africa to bacillary dysentery and other bacterial enteritides.

Certainly, flies and other insects can provide the means for the contamination of food and drink. However, the basic question in the epidemiology of amebiasis is, with any other enteric disease: Do they do this with sufficient regularity and sufficient volume to constitute a significant factor in the maintenance of the endemicity or the production of epidemics of amebiasis?

**WATER.** This medium must be seriously considered as a vehicle for the ingestion of the amebic cysts and a number of workers in the field feel this is the most important means of transmission. Accordingly, there has been a great deal of experimental investigation of cysts in water. It has already been noted that they survive longer in cold water than in water at summer temperatures, with rapidly shortening periods of survival as temperatures move above 25° or 30° C. Since the specific gravity of the cysts is not much above that of water they settle slowly, about an inch or two per hour in distilled water and more slowly when appreciable amounts of solutes or suspended organic material are present. Even in distilled water they are uninjured by the amounts of chlorine normally added to modern city water to protect against



bacterial contaminants and are at best only slowly killed in amounts of chlorine or iodine which render water unpalatable. Thus, cysts within water can remain available and viable for some time after contamination of the water. However, within a matter of days many of the cysts are lost by death or settling or both. If water is to remain a continued source of infection it requires a constantly recurring source of direct and heavy fecal contamination.

Apparently the transmission of amebiasis has been directly traced to water on only four occasions. Cysts were not recovered from the water, nor were they sought, but the gross fecal contamination of the water on each occasion leaves little room for doubt as to the cause of the outbreak. In the first of these, an epidemic in 1933 and 1934, traced to two Chicago hotels, three sources of direct and continuous fecal contamination were found, back siphonage from toilets, drainage from a defective sewer over the unclosed water cooler, and direct cross connections between sewer lines and water supply. Nevertheless, the attack rate was comparatively low in those with a short exposure as indicated below:

Duration of Stay in Days	Clinical Amebiasis per 1,000 Guests
1 . . . . .	3
7 . . . . .	11
8-14 . . . . .	13
30-90 . . . . .	111

The data, as Craig points out, are in accord with the view that large numbers of organisms are required to initiate an infection. Even with this massive exposure, the incubation period was 5 to 16 weeks for half of the cases, incubation periods for less than a week were reported in only 6 per cent of the cases. Under similar circumstances, an outbreak of diarrhea in the Mantetsu Apartment Building in Tokyo led to a prompt investigation (Davis and Ritchie, 1948). Sewage from a tank in the sub-basement had overflowed and submerged the main water line which was leaking and intermittently under negative pressure. Corrections were made before critical illness or deaths occurred but 63 per cent of the Americans quartered in the hotel and 22 per cent of their Japanese domestics became infected. The third example of this type is furnished by firemen in Chicago. Those fighting the stockyard fire in 1934 drank from the mixture of sewage used to fight the fire and 58 per cent were found to have *E. histolytica* as compared to 15 per cent in other firemen in the city. The fourth and most recent example occurred in a factory in South Bend, Indiana, during 1952-53. In this case a leak in the water line at a point where it was under negative pressure and submerged in sewage again provided for a continuing supply of direct fecal contamination in the drinking water. At least 30 cases (an attack rate of over 20 per 1,000), 2 deaths, and an infection rate of about 50 per cent developed before the situation was brought under control (Offutt and others, 1955).

Obviously, water can be the vehicle for transmitting the infection. Wykoff and others (1955) have called attention to the possible epidemiological significance of open wells as a more diffuse source of water-borne amebiasis in the Kofu Valley of Japan. However, the only direct incrimination of water as a source of infection has been under circumstances, outlined in the preceding paragraph, which provided for extraordinarily heavy, direct and almost continuous contamination of the drinking water with fresh sewage.

**MASS EXPOSURE: SUMMARY.** The preceding points have been considered in more detail than is usual in such a text for the dual purpose of making it clear that flies, infected food handlers, and drinking water are all capable of carrying the infection to man and to emphasize that there are not sufficient data available to determine the part they play either in maintaining the infection in any endemic area or in producing epidemics. Theoretically, it should be possible to establish the infection in a given individual with a single cyst. Actually, the direct feeding of a great many cysts to man or experimental animals may fail to establish the infection. Walker and Sellards established infections in only 18 out of 20 human volunteers who received thousands of viable parasites; one of the 18 required three such feedings. Furthermore, the infection was sufficiently severe to produce clinical amebiasis in only four. Recently, Taylor and his co-workers (1950) reported that injecting 1000 to 250,000 amebae intracably produced lesions in only 58 of the normal guinea pigs used. Sadun and others (1950) found that no infection resulted from more than 1,000 organisms and in only 1 out of 8 with 5,000; increasing percentages became infected with higher doses, but even at doses of 2.5 and 5 million not all guinea pigs became infected.

Both the laboratory and field observations emphasized that massive exposure is required to establish the infection in a large percentage of the population. Only in the tropics and subtropics with their climatic encouragement of promiscuous defecation, and under such specialized circumstances as in the Chicago epidemic, or the filthy conditions in some mental institutions, are highly endemic conditions maintained or epidemics developed with high morbidity and mortality rates. Except under special circumstances, such as the Chicago epidemic, it is impossible to determine whether food or water is the immediate source of the individual infection. In much of rural southeastern United States fecal material is more commonly found closer to the house than to the well or spring with the result that children, at least, playing and usually eating in contaminated yards, would have ample opportunity for immediate infection. As one moves from the endemic areas, sanitary conditions are, in general, better and the more subtle influence of flies and infected food handlers may help to maintain the generally low infection rate, with relatively little frank disease. However, one should not disregard the fact that even in cities, such as Baltimore and New York, there are elements of the population who have little or no regard for the sanitary code. The generally cooler climate in such cities provides for longer survival of the cysts than in such cities in the south and in part compensates for the smaller amount of fecal contamination.

**Immunity, Malnutrition, and Concurrent Infection.** There is no evidence in man or domesticated animals that a highly protective immunity develops as a result of the infection. Conversely, the disease is characterized by chronicity and relapse. Subclinical infections may persist for years; the writer and his colleagues had one infected animal attendant under observation who continued to discharge parasites in his feces for over a decade. However, this should not be interpreted to mean that there is no immune response. It seems probable that a low grade immunity keeps the infection under partial control and clinical breakthrough results from a temporary reduction in that immunity. Recently, Swartzwelder and Muller (1950) have shown that the injection of saline extract of *E. histolytica* into young rats before infection induced a significant degree of protection. Not only was complete protec-



tion against infection provided for a third of the rats but the observed lesion in those which became infected were only about half as extensive as in the controls. There is as yet no evidence that this has any practical value in human amebiasis but it does support the postulate that there is, at least, a low level of immune response in amebiasis. The possible significance of such immunity on the epidemiology and clinical course of amebiasis is extremely difficult to ascertain at the present state of knowledge.

It is commonly believed that resistance to the infection is lowered by malnutrition. The precise manner in which it occurs is not clear. It may in part reduce the body's capacity to respond immunologically. The most concise evidence of the possible role of malnutrition is afforded by experimental studies. Faust found that dogs on a balanced diet were more resistant to *E. histolytica* infection than those receiving a diet of salmon. Both liver and liver extracts were found to increase the resistance and would actually appear to be curative when fed to an animal suffering from acute dysentery. More recently, Taylor and others (1950) have found that diet has a powerful influence on the susceptibility of guinea pigs to *E. histolytica*. Reports from southern France have related increased *E. histolytica* infection to malnutrition during the war and postwar period. Over a quarter of a century ago, Fletcher and Jepps classified amebiasis in Malaya as a disease of poverty and want and noted that "dysentery vanishes before comfort and prosperity."

What role accompanying bacteria play in the production of clinical amebiasis is not clear. However, the recent report by Phillips and others that they were unable to produce amebiasis in germ free guinea pigs unless bacteria accompanied the amebae is of more than passing interest.

**Imported Amebae.** During both World Wars I and II troops from the temperate zones of Europe and America suffered significantly from amebiasis in the tropics. Concern has been felt over the possible aftermath of such infections in returning troops, both over possible relapsing amebiasis in the returning personnel and the possible transmission of the infections to the home population. Following World War I neither problem was encountered. In the present postwar period a number of veterans have required medical attention. The Veterans Administration reports the annual discharge of over 1,200 patients, admitted primarily for amebiasis in 1947 and 1948. However, routine surveys among nonhospitalized veterans have failed to demonstrate a generally high infection rate; from 3 to 10 per cent, which is not materially higher than the civilian population from which they were drawn. Lincicome and others (1950) compared the infection rate of veteran and non-veteran students at the University of Wisconsin with the following results:

642 veterans with overseas' service . . . . .	4.5%
282 veterans serving only in United States . . . . .	2.5%
184 nonveteran students . . . . .	1.6%

Further analysis of these data show a somewhat higher prevalence among veterans with tropical service. Other surveys have shown as much as 20 per cent in personnel from the China Burma India Theater. That these constitute a threat to the home populations seems very unlikely. If such veterans return to communities with poor sanitary habits and revert to the local habits, they will, of course, contribute their share to the community infection, but in such areas the infection is already high.

It is doubtful whether they can materially alter it. With good sanitary habits in the area they are no source of danger and where sanitation is generally good the danger is nil. These postulates are supported by the vital statistics which show no year increase in amebiasis among the civilian population.

**Control.** In a modern city the purification and treatment process of water is sufficient to insure its freedom from infection when it leaves the city mains. Its drinking thereafter may be considered a source of concern only under such gross abuse as characterized the Chicago epidemic or when otherwise contaminated after passing the faucet. Under such circumstances the dangers are not alone from amebiasis. The maintenance of sanitary handling of food, including fly, roach and insect control, in every stage of its preparation should not be dependent upon the possible danger from amebiasis. Lapses in these concepts may account for some of the subclinical amebic infection seen in the temperate zone. It is improbable that one can escape a nominal amount of exposure indefinitely but continued stress of good sanitary practice in handling food and water should contribute further to the reduction of the infection in the temperate zones. Specific attempts to prevent employment in food handling of individuals with *E. histolytica* infections has not been successful. It has been pointed out by the Committee on Amebiasis of the American Society of Tropical Medicine that such an individual constitutes no special hazard if he obeys the simplest concepts of personal hygiene and cleanliness. This committee and the U. S. Public Health Service have, therefore, recommended that efforts, legal and educational, be concentrated on the provision of adequate toilet and washing facilities and insistence on their use. It is further recommended that regulations designed to detect the infected food handler be eliminated, since medical certificates are commonly issued on superficial physical examination. The subclinical infection cannot be detected without fecal examination and to generally require such examinations would be costly, lead to deception and result in a false sense of security. Among military personnel or in specialized civilian installations in the tropics the periodic fecal examination of food handlers may have some value as an educational and disciplinary step. It would thus be significant only if used as one step in improving kitchen and mess hall sanitation.

A possible problem for correction in connection with large cities is the growing use of sludge from sewage disposal plants for fertilizer. However, both on theoretical grounds and the direct observations of Cram one may feel assured that the sludge resulting from a modern sewage disposal plant does not constitute a source of infection with *E. histolytica*.

Any attempt to reduce the transmission of amebiasis among the local population within an endemic area must take cognizance of the economic, sociological, and educational background. Customs and habits are a reflection of this background and are deeply entrenched. Sanitary improvements will come slowly and the process can be accelerated only to a very nominal degree. The significant problem of control, therefore, centers around protecting individuals or groups who may be transient, semipermanent, or permanent residents in the area. This would include military populations. When such groups, either civilian or military, are living together in a community and are large enough to either directly influence the sanitary control of food and water, or to provide their own installations of modern design, the principles that follow are not basically different from that in a modern city; these must be



adjusted around the local problems of source of supply. It is generally accepted that leafy vegetables such as lettuce raised and eaten where human feces is used as fertilizer may require treatment immediately before consumption to render them safe. The leaves of such vegetables should be separated and thoroughly washed with water. Attempts to enhance the cleaning effect of such washing by the addition of detergents or to kill cysts with chlorine or iodine preparations have not proved satisfactory. Therefore, even when eaten "raw" such vegetables should have a minimum period of heat treatment: either a brief immersion (less than a minute) in water above 80° C or longer immersion at lower temperatures (16 minutes at 50° C; 30 minutes at 48° C). Chilling immediately in a refrigerator or even in cold water after the treatment will provide a reasonable degree of crispness in lettuce for prompt serving. The use of acetic acid or vinegar on fresh vegetables may destroy some cysts but under conditions of ordinary table use will offer little protection. To concentrate such attention on leafy vegetables may neglect the fact that cooked foods prepared some time before being eaten may have a good opportunity to become contaminated where the sanitary level is such as to permit gross contamination of leafy vegetables.

Heat is also, in general, the most satisfactory method of rendering water of unknown purity free of viable cysts. Water brought to above 50° C and held for at least a minute will suffice; if a thermometer is not available, bringing the water to the boiling point will be more than sufficient.

For chemical sterilization of water under emergency field conditions, iodine offers advantages over chlorine. Its action is less affected by pH, temperature, and even the organic matter present. A recently developed compound for this purpose is tetraglycine hydroiodide (globaline) \* which is less unpalatable than the chlorine or other iodine preparations. One tablet shaken up in a canteen of reasonably clear water will usually kill cysts within 15 minutes; with highly colored waters two tablets should be used.

There is no therapeutic or other chemical agent with a demonstrated prophylactic value. Fifteen years ago Craig concluded that diodoquin would effectively serve the purpose and urged that its possible prophylactic value be evaluated by extensive field trial. He suggested that seven tablets (0.21 gm. each) be administered for 20 days and, if exposure continued, be repeated after one week's rest. So far there has been no demonstration that such a regime would be either effective or safe. However, the South Bend epidemic showed that mass treatment with either fumagillin or oxytetracycline will eliminate the infection from such a community. Nevertheless, neither is recommended for prophylactic use during continued exposure to infection.

**Treatment.** Of the therapeutic agents which have been extensively used, only emetine offers prompt relief of colonic amebiasis. Emetine is, however, not curative and must be followed by one of the arsenicals, such as carbarsone or one of the iodinated oxyquinolines, such as chiniofon (yatren, anayodin), diodoquin or vioform. One of the newer antimalarials, chloroquin has been shown by Conan and others (1950) to be effective in amebic hepatitis. Among the newer drugs which seem to offer considerable promise are such synthetic organic chemicals as milbimide and manatomide and such antibiotics as oxytetracycline, fumagillin and erythromycin.

\* There has been considerable misunderstanding on the chemistry of this material; in earlier literature it has been referred to as triglycine hydroiodide and triglycine hydroperiodide.

erson and others, 1954; McHardy and Frye, 1954). There is considerable difference of opinion as to their precise value in relationship to each other and to older organic compounds.

#### INFECTIONS WITH OTHER AMEBAE

Of the other species of amebae which have been reported from man, the question of possible pathogenic role can be seriously raised only for *Dientamoeba fragilis*. This small binucleate parasite is not readily seen in routine fecal examinations, and even smaller uninculeate stages are usually missed altogether. It is probable that infection is more common than generally revealed by routine surveys. Since the development of a supravital stain it has been found fairly commonly in a small series of examinations, and in 1937, Wenrich, Stabler, and Arnett reported 4.3 per cent among over 1,000 students in Philadelphia. Usually, no clinical manifestations or history of such manifestations are associated with the presence of these organisms. The increasing number with recurrent episodes of abdominal distress and bouts of accompanying diarrhea suggests that this organism should be kept under suspicion. Hakansson (1937) has included burning sensations on defecation as one of the characteristic manifestations. Treatment with carbarsone as for *Entamoeba histolytica* is said to alleviate the symptoms and remove the organisms. Since cysts of this organism are unknown, it is generally assumed that infection results from ingestion of the trophozoites. Little is known of the epidemiology except that in an insane asylum Hakansson found 16 new infections in 38 patients within a year after successful treatment for *E. histolytica*. It is assumed, then, that it is a fecal-borne disease as the other amebic diseases, and flourishes where encouraged by unsanitary habits of fecal disposal. No specific control measures can be recommended.

*Entamoeba coli*, *Endalimax nana*, and *Iodamoeba williamsi* \* (= *I. butchlii*) may be dismissed as harmless commensals. They are of concern only to the extent that their presence in the feces may be a source of confusion in the attempt to determine by microscopic examination whether or not *E. histolytica* is present. For instance, to assume that any active trophic ameba in a dysenteric, diarrheic, or bloody stool is *E. histolytica* is to disregard the fact that the same stage of any of the above amebae will occur in such stools if the patient harbors the organisms. *Entamoeba gingivalis* is a nonpathogen of the mouth which occurs only in the trophic stage. No cysts are known. Since these amebae do not ordinarily survive passage through the stomach they do not even offer sources of complication in the microscopic examination of feces; transmission of this form is by kissing.

#### BALANTIDIASIS

*Balantidium coli* normally occurs in swine but is also found in the guinea pig and the chimpanzee. Its presence in these animals is not associated with any pathology, but in the colon of man flask-shaped ulcers not unlike those of amebiasis are produced, and chronic or recurring diarrhea or dysentery results. Fortunately, infection in man is comparatively uncommon but the several hundred cases which have been reported are widely scattered over the world. It is most commonly found in those with conspicuously close association with hogs, such as swine herders and gut strip-

\* Derrick (1948, Tr. Roy. Soc. Trop. Med. & Hyg., 46:41-42) reports the finding of an organism indistinguishable from *I. williamsi* in the alimentary canal and other tissues, including the nervous system, in a postmortem examination in the Pacific.



pers in abattoirs. Most human infections, therefore, appear to have resulted from the ingestion of the cysts of these ciliates of porcine origin. However, Young (1937) found 5 per cent infection in patients in a mental institution removed from any immediate porcine contact but living under grossly unsanitary conditions of their own making. The introduction of a single infected individual into such an environment provides excellent opportunity for transmission and does not contradict the premise that most infections have an immediate porcine source. As with amebiasis, control under such conditions is unremitting sanitary disposal of feces. The transmission from pigs to man is, perhaps, more subtle but should be readily interrupted among such handlers by washing the hands and preferably also changing clothes before eating or otherwise bringing the hands to the mouth. Treatment is with carbarsone, as in amebiasis, and is successful according to Young and Burrow (1943).

### FLAGELLATES AND FLAGELLATE DIARRHEA

It is doubtful that any of the intestinal flagellates produce diarrhea with an degree of regularity. Certainly, *Trichomonas hominis* and the small flagellate *Embadomonas* (*Retortomonas*) *intestinalis* and *Enteromonas* (*Tricercomonas*) *hominis* may be completely discounted. Recurrent diarrhea has been reported associated with *Chilomastix mesnili* infections but the diarrhea appears to develop often after the demonstration of the organisms as before such demonstration. There is more suspicion that *Giardia lamblia* may produce diarrhea. Diarrhea, epigastric pains, nausea, and migraine-like headaches developed in one accidental laboratory infection of an adult and terminated upon chemotherapeutic removal of the organisms. In Europe, celiac syndrome in children has been associated with the presence of these organisms but they may have been only a source of confusion or at most a complication. The infection is most common in children in the first decade and this age group prevalence rates as high as 30 per cent have been reported without any indication that the organisms were more than harmless commensals. Perhaps in the initiation of the infection or with particularly rapid multiplication they may be troublesome. Prevention is essentially as in amebiasis.

Although not an intestinal form, *Trichomonas vaginalis* may be mentioned briefly here. The infection is transmitted primarily by coitus but infection of female baby may take place at birth; such infections appear to be of short duration (Trussell, 1947). Infection rates of 10 to 70 per cent have been reported in adult women in the United States and Europe. In general, the infection rate in Negro women is about twice that in white women of the same age groups in the United States. Within each race the infection rate is highest in the 20 to 40 age group. The infection seems to be somewhat more common in pregnant than nonpregnant women. Few adequate surveys have been made of males but recent surveys have revealed that it is much more common than formerly supposed. As with women, Negroes appear to be much more frequently infected than whites; Roth reported 25 per cent in the former and 4 per cent in the latter and Feo found 17 and 12 per cent, respectively, in the two races. There is no demonstrated pathology or symptomatology in the male and most females harbor the infection without manifest difficulties. However, both in natural and experimental infections a small portion of the women, particularly pregnant women or nonpregnant women immediately after menses, v

er extensive inflammation of the vaginal mucosa with a characteristic frothy discharge. Prevention is similar to that in other venereal infections but complicated by the fact that most of the infections in women and apparently all the infections in men are asymptomatic and hence not usually detected. Treatment is not wholly satisfactory but the best results have been obtained from adjusting the pH of the vaginal tract. The organisms in culture grow best at pH 5.5 to 6.0 and the heavily infected tract has the same pH range. In culture or in the vagina, growth apparently never takes place below pH 5.0 or above pH 7.5. Thus, acidification or further alkalization of the tract appears to be beneficial but, since the normal pH is 4.0 to 5.0, acidification is more readily induced and the beneficial results are more quickly obtained and relapse appears to be less likely.

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DISEASES AND INFECTIONS DUE TO INTESTINAL  
HELMINTHS

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## ANCYLOSTOMIASIS

Recently, Stoll estimated that 457 million people or nearly a quarter of the world's population are infected with hookworm. However, not all the infected individuals show evidence of disease, and in some areas, the portion of the infected populace who suffer demonstrable ill-effects is relatively small. The chronic anemia and debilitation usually associated with the infection is not produced by hookworm alone. Malnutrition is invariably a factor which permits continued infection and reinfection (Cort and Otto, 1940). Long standing "hookworm disease" is then the product of malnutrition and continued blood sucking of the worms. Both laboratory studies and field observations suggest that it is impossible for chronic debilitating hookworm disease to develop in the otherwise healthy individual. Uncomplicated hookworm disease is rarely seen. It occurs only as an acute hemorrhagic disease produced by a large number of worms acquired at one time or in rapid succession over a short period of time.

Historically, hookworm is significant since it was this disease which challenged the organization of the Rockefeller Sanitary Commission out of which grew the International Health Division of The Rockefeller Foundation. This disease was also the direct stimulus for organizing many rural health departments in southern United States and abroad.

**Adult Worms.** The two species of hookworm of man are the Old World hookworm or European hookworm, *Ancylostoma duodenale* and the so-called American hookworm, *Necator americanus*. The former is the more pathogenic and the larger of the two (males 8-11 mm.; females 10-15 mm.) and armed with cutting teeth in the mouth parts; the latter is smaller (males 7-9 mm.; females 9-12 mm.) and has less effective cutting plates in the mouth. There is also some evidence that the former is more resistant than the latter to chemotherapy. Both species are confined to man. The common hookworm, *Ancylostoma caninum*, of dogs does not infect man. However, much of our knowledge of hookworm disease has been gained through the experimental study of this species in its normal host. Another hookworm, *Ancylostoma braziliense*, of dogs and cats in the tropics will penetrate the skin of man but does not normally complete its development in that host. It may migrate in the hypodermis for weeks or even months before it dies and thus produces the condition known as creeping eruption.

**Life Cycle and Method of Infection.** The adult worms live in the small intestine, where both the males and females remain attached to the mucosa and suck blood. Laying appears to be an almost continuous process. The eggs are in the early cleavage stages (2 to 16 cells) when passed in the feces. These mature and hatch within 24 hours. The first stage or rhabditiform larva feeds on bacteria, grows, and moults into the second or transitional stage which in turn feeds, grows, and moults to the third stage or filariform larva; this is the infective larva. Under optimum conditions the infective larvae appear within a week after eggs are laid, but at sub-optimum temperatures may require 10 days to two weeks. The infective larvae do not feed but may survive for weeks or even more than a month under suitable circumstances. They do not migrate laterally but will migrate vertically to reach the surface. However, effective vertical migration is limited to moist soils with a moist surface. In a moist, sandy soil a few may migrate vertically to reach the surface but even under these conditions less than half of them will reach the surface alive from a depth of more than a foot. With clay soils or dry soils vertical migration is further reduced.

Infection normally takes place by the active penetration of the larvae through the hair follicles or abrasions of the skin; they can also penetrate the mucous membrane of the mouth and apparently they may become established when swallowed. The larvae do not migrate directly from the skin to the intestine but enter the venous circulation and are carried to the lungs where they break into the alveoli, ascend the trachea, and are swallowed to reach the intestine. Growth and maturation in the parasitic phase involve two additional moults and require over a month. The first eggs appear in the feces about six weeks after the larvae penetrate the skin.

It is evident that a few adult worms may live in the intestine for more than five years and perhaps as long as 10 years. A number of lightly infected individuals living under conditions which appear to preclude the chance of reinfection have continued to pass eggs in the feces for well over seven years. It is equally evident, however, that most of the adult worms survive for only a short period of time. The rate of loss is largely a function of the immunological status of the host as will be noted later. It is possible to generalize, however, to the extent of saying that most of the worms are lost in less than six months.

Egg production of the worms is also influenced by a number of factors such as age and number of worms, nutrition and interrelated immunological status of the host. On the average, however, the female of *N. americanus* lays about 8,000 to 10,000 eggs per day and *A. duodenale* about twice as many. Fecal examinations for hookworm eggs are an invaluable procedure both to the clinician and the epidemiologist. Effective use of the technic requires an appreciation of the quantitative aspects of the infection. In the clinical laboratory, the simple saline smear is completely inadequate. It is true that some very light infections will be missed but it is hardly conceivable that any infection heavy enough to produce clinical manifestations will be missed; in fact, a great many subclinical infections will be discovered. Accordingly, except for special studies, concentration techniques such as by brine flotation or by zinc sulphate flotation, while suitable, are unnecessary.

For epidemiological studies it is desirable to use some quantitative measure of infection. For this purpose the Stoll dilution egg counting method has had the widest use and has the virtue of being simple. Recently, Beaver has reported the use of the



photo-electric measurement to standardize the saline smear and, by counting the eggs in this standardized smear, has obtained a quantitative measure of the infection. For years the Georgia State Health Department has obtained some quantitative measure of the infection by the use of a quantitative brine flotation. A standard amount of feces is used (1 gm.) and the quantity of eggs recovered are roughly classified as 1, 2, 3, and 4 plus. Any of these quantitative technics may be employed but the Stoll dilution egg count has had the most extensive use in critical epidemiological studies. A reasonable estimate of the number of *N. americanus* present may be obtained by dividing the number of eggs per gram of feces by 25. The variations are such, however, that any attempt to determine the number of worms in a given individual from a single stool examination will be subject to large errors.

**The Disease.** Chronic or recurring hookworm disease is characterized by continuous or recurring hypochromic microcytic anemia. As already noted this condition results from the bloodsucking activity of the worms and a predisposing malnutrition. It is remarkable how a severely infected individual can survive but deaths are not common. Rather there is produced a state of chronic debility. The anemia may result in a compensatory enlargement of the heart and children may be mentally, physiologically, and physically retarded in their development. In the individual sensitized by repeated infections, "ground itch" due to the penetrating larvae may be severe.

Severe outbreaks of acute hookworm disease have been described. Ashford and others (1933) reported one such outbreak involving a whole family of good nutritional status which had received an unusually heavy exposure to infection. The provisional diagnosis was established early, before eggs appeared in the feces, on the basis of the extensive but mild ground itch, followed by pulmonary symptoms and the development of severe anemia within three weeks accompanied by black tar-like stools and a marked eosinophilia (up to 80 per cent). Diagnosis was confirmed by treatment which removed thousands of immature worms and initiated rapid recovery. Such outbreaks are rare, but hookworm disease should be considered when transients, such as military personnel, in the tropics or subtropics are found to have a rapidly developing anemia due to blood loss through the intestine.

**Geographical Distribution.** Both of the species of hookworm of man have become widely scattered.

Although *N. americanus* was first described from the United States and thus commonly referred to as the American or New World hookworm, it appears to have originated in tropical Africa or southern Asia from which it has spread widely. Certainly it was brought to the Western Hemisphere from Africa in the Negro slaves. It now extends from the southern United States through the American tropics to the temperate zone of South America. It is the only common hookworm of man in this hemisphere and in most areas is present to the complete exclusion of the Old World hookworm. In Africa, it is largely confined to Central and South Africa with its most northern extension along the west coast to about 15° N. In southern Asia, it is the exclusive or dominant species but overlaps with the European hookworm in central India and central China. Similarly, it is the dominant species in the Western Pacific Islands, including Okinawa, Formosa, the Philippines, Java, Sumatra, the Celebes, New Guinea, North Eastern Australia, and Fiji.

4. *duodenale* may be classified as the temperate zone hookworm. It is the hookworm of the agricultural regions of the Mediterranean area, North Africa, Asia and Europe. Farther north in Europe it is found principally in the mines. As in the mining-like operations in the construction of the St. Gothard tunnel a severe epidemic developed in 1879 and provided the first indication of the significance of hookworm as a disease-producing organism. It is still a problem in some of the mines of central Europe, and was once a source of concern in the mines of England and Wales. Similarly, the introduction of this species into the gold mines of California by European miners created a serious problem which was brought under control over a quarter of a century ago. This species had undoubtedly been brought to this hemisphere in a great many immigrants from Europe but it has developed only into a few local foci in the rural areas of South America. Interestingly enough, it is found in a few of the native Indian tribes in South America who had little if any contact with Europeans.

This species is most prevalent in Central Asia. It is the exclusive species in northern India, north and central China and overlaps with *N. americanus* in central China and in central and south China. It is the dominant or exclusive species in Japan and the central Pacific Islands. It appears to be the exclusive species in the outback of western Australia.

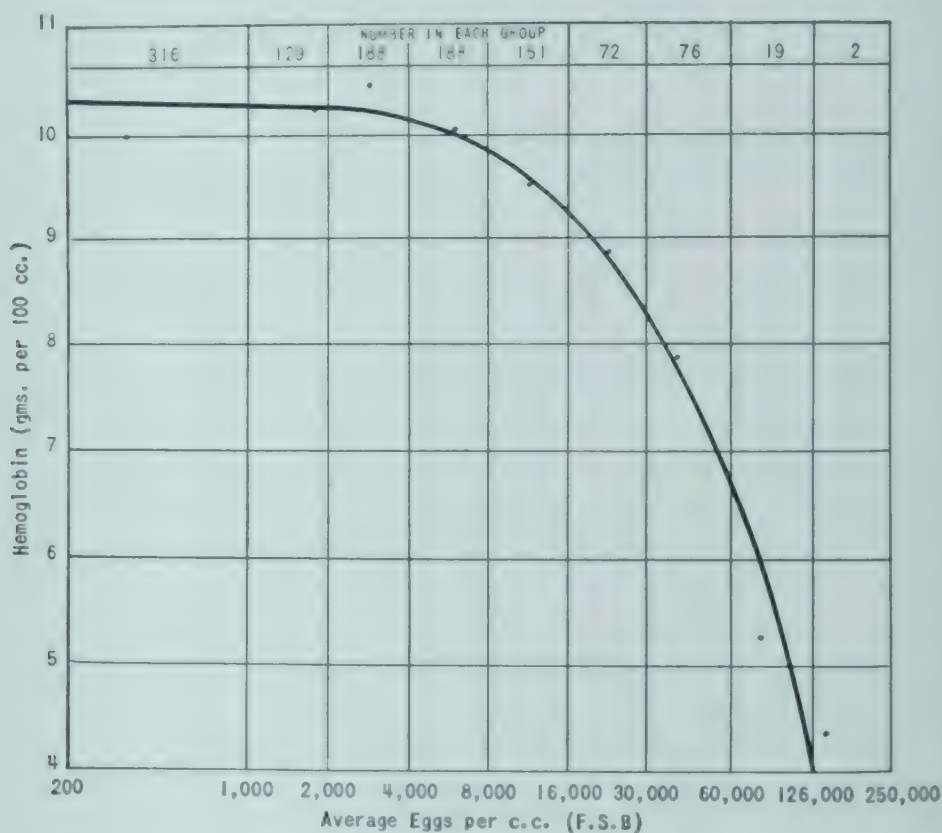
It must be recognized that these generalizations on the geographical distribution of the two species rest on a limited amount of data. It is not possible to distinguish the species by examination of the eggs. Hence precise information on the geographical distribution can come only from observations on post-treatment or post-mortem examination of the adult worms. However, the epidemiological factors governing the distribution of both species are similar and may be discussed together. Furthermore, infection is not uniformly distributed throughout the broad geographical areas indicated. There may be little disease even where the infection is common, while in another area, without a materially higher percentage of infection, hookworm disease may be a serious problem. In the United States, the infection is largely confined to the southeastern part of the country and manifest disease is found only on the sandy coastal plains and a limited number of sandy valleys or plateaus in the adjacent mountain areas. Figure 3-8 (Hill and Andrews, 1942) shows the variations in the density of hookworm in a population correlated with hemoglobin concentrations. These observations were made in south Georgia where 40 to 50 per cent of the rural population are positive for hookworms. Of the 1,141 positive individuals under observation, less than 30 per cent were passing 8,000 or more eggs per gram of feces and had a measurable deficiency in hemoglobin. It is estimated that 8,000 eggs per gram indicates the presence of more than 300 worms. Thus, it may be said that somewhere near 10 to 15 per cent of the population from which this sample was drawn suffer demonstrable injury from the hookworms.

The various interrelated factors in the development and maintenance of hookworm infection and hookworm disease can be summarized under three broad headings: environment, human habits, and intrinsic host factors. The latter may be conveniently subdivided under race, immunity, and nutrition or malnutrition.

**Environment.** The free-living stage of the hookworms develops and survives in a moist, shaded, and warm environment. Temperatures of 75° to 85° F appear to be optimum but development is not materially retarded by occasional temperatures as



low as 70° F. Below 70° F development is retarded and is never completed at temperatures as low as 45° F. Above 85° F development may appear to be temporarily accelerated but may never be completed at high temperatures. A loose, sandy soil, with or without a high humus content, provides a good culture medium. Rocky soils or those containing a high clay content are unsatisfactory for the development stages. Laughlin and Stoll (1947) have shown that development readily takes place on bed clothing or wearing apparel which remain damp. Such clothing appears to offer optimum culture conditions since large numbers of larvae were demonstrated in the absence of visible contamination.



From Andrews, J., Am. J. Pub. Health, 32, 1942, Fig. 3.

Fig. 3-8. Average hookworm egg counts and hemoglobins, by egg-count classes, in 1,140 residents of South Georgia (curve fitted by inspection).

Drying is rapidly fatal to the larval stages and even the eggs will not survive long without moisture. Winds and sun contribute to the drying and the latter adds the lethal effect of heat. Thus, for the most part, only shaded soils offer the opportunity for development. When the surface of the soil is dry, some of the larvae may remain in the moist subsurface and emerge as rains or heavy dews provide sufficient moisture. However, there does not seem to be any tendency to burrow downward to moisture, and many are caught on the dry surface where they perish. Thus, rainfall or irrigation is important in providing adequate conditions for development. In general, even with widespread fecal contamination of the soil, relatively little hookworm disease develops when there is less than 40 inches of rainfall per year. In southern Georgia with about 50 inches of rainfall a year most of the transmission appears to take place during the limited periods of the spring or early summer and

in the early fall when repeated rains maintain a moist surface. During the summer when rains are less frequent and during the cooler winter months little or no transmission takes place.

Although the eggs and larvae require moisture, standing water does not provide suitable conditions for development, largely due to the low amount of oxygen at the bottom. However, temporary rain pools may provide points of concentration by drawing both eggs and larvae into these low spots.

**Human Habits.** Hookworm infection is sharply correlated with those human habits which concentrate feces in moist shaded places which are repeatedly visited. Only nominal attention to proper fecal disposal may be sufficient to prevent the spread of the infection. Even the unsightly and malodorous open-back privy, if persistently used, concentrates fecal material so that there is less chance of exposure. In the absence of any privy or in disregard of its presence, as in the poorer sections of the southern United States and in tropical America, fecal concentration is seen in secluded shaded areas near the house and continuous return to the same area provides a constant source of reinfection. Among the more careless elements of the population the feces, particularly of children, are often concentrated in the immediate proximity of the house (Otto and others, 1931). Under such conditions the family is the unit of infection and families in which all or most of the members suffer severely from hookworm disease may be found living close to other families with relatively little infection. Defecation in fields of growing crops is more diffuse and may help spread the infection but does not provide the concentrated sources required to produce severe disease, except under special circumstances. About the old one-room rural school houses, with inadequate toilet facilities, or none at all, fecal contamination was concentrated in the adjacent woods, by the girls on one side and boys on the other. The development of the consolidated rural school has tended to reduce this community source of infection. Chandler reports similar household and village fecal contamination in India. Scott and others (1934) found fecal concentrations between houses in the villages in Palestine. In Egypt, where there is relatively little wild vegetation and no habit of seeking concealment, defecation takes place in the street, yard, and fields indiscriminately (Scott, 1937). Soil contamination is widely distributed and the arid winds destroy much of the potential infection quickly. Thus, while hookworm is widespread in Egypt, the infections are very light and hookworm disease is rare.

Hookworm disease is directly or indirectly an occupational hazard in a number of ways. Mention has already been made of the disease in the miners in Europe and California. Transmission under these circumstances is exclusively, or almost exclusively, a result of uncontrolled defecation in the mine passages. There, constant moisture and an even temperature provide for the maximum life of the worms with ample opportunity for infection. The exposure is largely suffered by the adult males who work in the mines. The brick-maker's anemia of Italy and Germany in the past century was the result of a similar concentration of hookworm infection where the men worked. In this connection mention should be made of the infection of laundry sorters who became infected at the Navy laundry on Guam as a result of sorting soiled clothing which had been allowed to accumulate a week or more in a damp place before being laundered.

The best examples of the occupational relationship to infection among agricul-



tural workers are in silkworm and sweet potato cultivation in China. In the Yangtze Delta and in Kwangtung Province mulberry trees are grown for the sole purpose of providing leaves for silkworm cultivation. After the spring crop of leaves is picked the ground is cultivated and trees fertilized with a liberal application of night soil to force the next crop of leaves. The night soil used is both that which has been stored for some weeks or longer, in which most of the hookworm eggs have died, and the fresh night soil from the local population which contains viable hookworm eggs. Thus, the moist, shaded areas under the small trees are teeming with infective larvae when the next crop of leaves are picked. Cort reports as many as 10,000 infective hookworm larvae from a single soil specimen taken from the base of a mulberry tree at the time of the second picking of leaves. Ground itch annually occurs among the mulberry pickers at this time, and is followed by a cough (from the migrating larvae), and later by anemia. There must be a considerable loss of worms in the intervening year since with many individuals this sequence of events is an annual occurrence. All elements of the population are involved but since the picking of the mulberry leaves is primarily assigned to the women they are the ones who suffer most. However, in Szechwan Province the extensive mulberry raising is not associated with the spread of hookworm disease due to differences in practice. In this northern province the leaves are only picked once, in the spring, and trees are fertilized with night soil after the picking. Eggs and larvae could not survive until the next season. Furthermore, the trees in this area are allowed to grow tall so that leaves are picked from ladders which reduces contact with the soil and thus reduces the opportunity for infection even if the night soil were applied before the leaves were picked.

The sequence of events in the cultivation of sweet potatoes in Szechwan Province, however, provides opportunity for massive infections. Corn is planted and fertilized with night soil and weeks later, when the infective hookworm larvae are abundant, sweet potatoes are planted by hand thus permitting infection both through the hands and feet. In Fukien Province sweet potatoes are fertilized when planted and at least twice thereafter. The sweet potato runners are loosened by hand 15 to 20 days after each fertilization, when the infective larvae are abundant (Tang, 1949).

Although night soil is used to fertilize other crops, working is less consistently timed with fertilization by night soil. Furthermore, some crops, such as cotton, are grown on drier soil. Accordingly, hookworm disease is less prevalent in most agricultural workers than is the case with the silkworm culturists and the sweet potato gardeners. Rice cultivation actually offers protection from hookworm infection. The eggs do not develop in the night soil poured around the submerged rice plants and die in the water.

Both in the coffee groves of Puerto Rico and the orange groves of Palestine, promiscuous defecation among the trees provides scattered sources of later infection for the coffee and orange pickers but not the concentrated sources provided for the silkworm culturist and sweet potato gardeners of China.

**Intrinsic Host Factors. IMMUNITY.** Experimental studies have shown that dogs are capable of and do develop a highly protective immunity to *Ancylostoma caninum* (Oto, 1948), the normal hookworm of dogs. If a few larvae (15) are administered at weekly intervals for a month, and thereafter the dose is increased at weekly intervals, only a few worms—usually less than 200—will develop and survive and the animal will remain healthy and free of signs of hookworm disease.

though the final dose of larvae three to six months later is as high as 200,000. Mates receiving only the final dose of 200,000 invariably die within two weeks in blood loss and 10,000 to 50,000 worms are recovered at necropsy. When, however, the process is accelerated either by more frequent administration of the larvae or by more rapidly increasing the doses many worms become established and there is a rapidly developing anemia. A crisis is reached in a relatively short time either the animals succumb shortly thereafter or else the worms are discharged and the animals rapidly improve in health, *even though more infective larvae are continuously administered*. Such animals have been shown to be thereafter refractory to as many as a million larvae administered at one time. Quantitative aspects of this immune phenomenon have been clearly demonstrated. Puppies receiving a single dose of 300 to 600 larvae appear to be immune after two months to challenge doses of 10,000 larvae but are not immune to, and may be killed by, challenge doses of 100,000. However, initial doses of 1,200 to 1,400 larvae will render a puppy immune to 50,000 larvae. The serum of immunized dogs contains antibodies which form precipitates with the secretions and excretions of the infective larvae in vitro block the oral opening, and often the excretory pore as well. In the tissues of the immune animal the migrating larvae are retarded, apparently as a result of this precipitin reaction and thereafter are destroyed in the tissue reaction. Most of them appear to be arrested in the skin. Very few complete the migration to the intestine, and most of the latter fail to become established.

It seems probable that the phenomenon in man is similar. Only one experimental study with one human volunteer has been carried far enough to offer data on the subject. This individual received slowly increasing doses of larvae, a total of 5,000, over a two-year period following which a challenge dose of an additional 5,000 larvae was given. At no point in the study did the individual show any diminution of hemoglobin or loss of weight; in fact, there was a slight gain. Effective treatment and complete recovery of the worms revealed only 300 worms resulting from the total of 10,000 larvae.

It will be noted that in the one human subject and even in the hyperimmunized dogs some worms survived the immune process so that, insofar as the worms are a measure of immunity, it cannot be classified as absolute. If, however, immunity is measured, as it is in bacterial or virus infections, in terms of disease, then the immunity to hookworm is absolute. The first attacking larvae protected the host efficiently from subsequent attacks of larvae to prevent either a relapse of the disease or the development of a new attack. If immunity to hookworm were as effective in nature as it was in these experimental studies, chronic hookworm disease would never develop and only acute hookworm disease would be of concern. Obviously, there is some discrepancy between the experimental studies and the field observations, since hookworm disease is a chronic debilitating type of disease in many parts of the world, and with a considerable number of people it is a problem through much of their life.

**Intrinsic Host Factors.** NUTRITION AND MALNUTRITION. Wherever hookworm is common the chronic debilitating type of infection is seen in the lower economic groups of the population. The most superficial inquiry is sufficient to reveal the fact that such people do not receive a balanced diet and often the caloric intake is inadequate. The most conspicuous lack is usually animal protein, but the vitamins



are frequently lacking also. Obvious specific deficiency states may be recognized but more often they are not evident. Rather the nutritional condition may be considered as being marginal.

Experimental studies with a number of worm infections in a variety of hosts, but particularly those with *A. caninum* in the dog and the closely related *Nippostrongylus muris* in rats, have revealed that the nutritional status of the host has a powerful influence on ability to combat the infection. In many cases a much larger percentage of worms from an initial infection will become established in the malnourished host than in the control receiving a balanced diet. The differences, however, are less conspicuous and less consistent than those associated with exposure to subsequent infections. Foster and Cort found that dogs on a protein- and vitamin-deficient diet failed to develop the degree of immunity, as a result of repeated exposure to infection, which their litter mates on balanced diets developed. Furthermore, animals which were immunized while on a balanced diet became susceptible to infection when fed the deficient diet and *lost the infection again when* returned to the balanced diet. Donaldson and Otto (1946) later showed a similar relation of protein in the diet to immunity in rats exposed to *N. muris*.

A quarter of a century ago Fülleborn found that in the cattle raising areas of the Argentine where nutritional conditions were good there was very little hookworm disease. The lack of sanitation on a sandy type of soil and in a warm climate seemed to offer a favorable environment for transmission; a 40 per cent infection rate demonstrated that transmission took place. Fülleborn, at that time even before the experimental demonstration of the immune phenomenon in this infection, suggested that immunity played a part in the protection of these well-nourished Argentinians. Among the populations of the world who maintain hookworm infection by their defecation habits in a suitable environment for transmission, there is every gradient in the nutritional status from that of Fülleborn's Argentinians to the completely undernourished conditions seen in some of the poorest hookworm families of the southern United States, in China, and elsewhere. Thus, there are various levels of immunity affected by nutrition. The limited number of observations which have been made on the temporary improvement of the diet of malnourished hookworm patients have shown that some amelioration of the anemia may result and worms may be lost without specific chemotherapy.

The observations of Cruz in Brazil also emphasize the nutritional factor in hookworm disease. Since the hematopoietic system appears to suffer little or no irreversible damage he finds that the addition of iron to the diet will stimulate hematopoiesis and the anemia can be corrected without the removal of the worms. Where the iron deficiency is a conspicuous part of the picture and the limited iron resources are further depleted by the blood sucking activities of the hookworms the specific addition of iron is significant. However, dogs infected with hookworms while receiving diet deficient both in iron and protein, as well as vitamins, showed only a transient hematopoietic response to the administration of iron (Otto and Landsborg, 1940). Under these circumstances continued administration of iron did not affect the ultimate fate of the dog or the worms. Similarly, Payne and Payne (1940), working with a population in Puerto Rico whose diet was deficient in protein as well as iron, found that supplementary iron was beneficial for only a few months; thereafter, anemia again developed despite the continued use of iron. The reason is

ent when one considers that iron is but a small portion of the hemoglobin molecule. Protein and other dietary constituents appear to be required for the formation of hemoglobin as well as for the development of immunity.

**Intrinsic Host Factors. RACE.** The Negro is much less susceptible to hookworm, at least to *N. americanus*, than any of the other human races. In Africa, there may be a high infection rate with relatively little disease but in the United States Negroes living under the same sanitary conditions as the whites will usually show no evidence of hookworm disease and a much lower percentage of infection than the latter. The reasons for this are not at all clear. Various explanations have been offered, all of which are postulates, and any of which may have at least some significance. Since *N. americanus* appeared early in Africa it is probable that there has been some natural biological selection over the centuries. It has also been postulated that the hookworm may find it more difficult and often impossible to penetrate the thicker skin of the Negro. However, racial differences in susceptibility to other worm infections are known to occur with a number of species of animals in which skin penetration is a factor. Thus, at the present state of our knowledge it is not necessary to invoke a difference in skin thickness to explain the difference in racial susceptibility; there is no precise support for the postulate, but it cannot be completely disregarded on that account. In the southern United States, at least, there is another very consistent difference between the rural Negro and his economic counterpart, the poor white sharecropper. The latter families, whether they harbor hookworm or not, frequently have thin, underweight, and may look emaciated. The Negro children and young adults, at least, have a well-fed look about them and are generally heavier. To what degree this difference is genetic and how much it reflects a difference in the utilization of the limited resources and opportunities to get food is not clear. Furthermore, whatever role this plays in the relative susceptibility of the two races to hookworm is not known. In short, the underlying mechanism of the difference in racial susceptibility or immunity is not known but warrants careful investigation.

**Prevention of Hookworm Disease.** The prevention of hookworm disease is most logically considered with reference to that portion of the population whose sanitary habits are such that they do not maintain their own sources of infection. This would include transient, semipermanent, and permanent populations, both civilian and military, living in the endemic area.

It is necessary only to prevent contact with infested soil. This is almost completely accomplished by wearing shoes, and for the most part no other admonition is needed. A few special points may be mentioned in addition. Children, particularly young children, should be prevented from wandering into unsanitary areas where by playing on the ground various parts of the body may come in contact with the infested soil. Temporary rain pools or pools replenished by heavy rains should be avoided for wading or swimming if they receive washings from privies or slopes on which defecation commonly takes place. Sea water, however, does not constitute a hookworm hazard. Military personnel on training or combat maneuvers may find it difficult to avoid contact with infested soil. Clothing, such as uniforms, which will amply protect against the infective larvae under most circumstances, and the handling with bare arms and hands of the unwashed bed clothing or personal wearing apparel of infected individuals should be avoided if such clothing is stored more than five days, particularly when it is damp and warm.



**Control of Hookworm Disease.** Theoretically, it should be possible to control hookworm disease in the indigenous population within an endemic area by the simple expedient of providing privies or shoes for everyone. The difficulty results from the fact that the severe form of hookworm disease is found only among the economically unfortunate group of the population. Living as they do on a marginal basis, only the bare necessities of life are provided, and in the absence of climate pressure for protection, privies and shoes are of minor concern or scarcely even considered. Against this economic background sociological habits have developed. Shoes, when provided, may be worn as a matter of pride on occasion but not for comfort or as protection. When a privy is provided through official or private means, even when built by the members of the family, it is indifferently used. The "privy habit" does not develop easily against such a social and economic background.

The problems are equally complex where night soil has an economic value as fertilizer and agricultural habits are intrenched.

Nevertheless, some progress has been made in the slow process of education. The several approaches and results may best be considered under a series of sub-headings.

**MASS THERAPY.** The earlier attacks upon the hookworm problem centered around treatment. Two basic approaches were used: (1) the treatment of all those found positive on routine fecal examination, or (2) treatment of all personnel, regardless of the individual infection status, when a preliminary survey revealed that the infection was common. In many respects this is the easiest official approach to the problem since it requires the minimum cooperative effort on the part of the individual. However, at best, treatment alone does little more than put a worm-free episode into the life of the infected individual. It requires periodic repetition. In both the individual and the community the pretreatment level of infection is quickly restored. Sawyer showed the return of the hookworm population follows the same trends and ecological experiences as free-living populations. The more effective the treatment, the more rapid is the immediate rate of reinfection, and complete reinfection to the pretreatment level may take very little longer than with less effective treatment. It may take no more than three to five years to completely nullify the effects of treatment in a community. Treatment alone, even with continued repetition, has not been successful in the control of the disease. It has, however, proved to be a valuable introductory and supporting measure; it is a means of gaining the confidence and cooperation of the populace and at the same time gives the treated individual a temporary period of improved health. Treatment is then an important part of the control program. Tetrachlorethylene is the drug of choice, and the adult dose is 5 ml. preferably without any purgation (Carr and others, 1954).

**PRIVIES.** The basic issue is how best to interrupt transmission in a permanent manner. This interruption cannot be accomplished without the direct and active personal cooperation of the populace involved. The provision of sanitary facilities does not insure their use. Since the problem of providing sanitary facilities in the control of hookworm disease is basically in the poorer rural population, the privy is the only facility which can be seriously considered. It is desirable to enlist the active participation of the individuals in the construction of the privies. Hence they should be simple. They should preferably be such that the infected families can provide

within the limits of their resources (see material on sewage disposal, page 42).

Stress is put upon the privy at the home because much of the hookworm, outside China, is transmitted in this environment. However, similar provisions should be made where agricultural workers will find them conveniently available in the field.

The provision of privies in mines has eliminated the problem in such cases. Apparently, however, there are still some mines which have not yet been adequately provided with these facilities.

**NIGHT SOIL.** The economy of much of China is geared to the use of night soil as fertilizer. Any attempt to completely eliminate the practice would create as many problems as it would solve. Fortunately, hookworm eggs and the eggs and cysts of most other intestinal parasites can be killed by the simple expedient of storing. In most areas the principle of storage is already used in both urban and rural areas. The object is to accumulate this fertilizer for application at particularly specified growth stages of the crop in question. Considerable success attended efforts in China before the war to bring about standardized storage practices. Many of the eggs are destroyed in less than a week but two to six weeks may be required to kill all of them in the summer under various types of storage. The addition of unslaked lime or ammonium sulphate will hasten the process but the addition of these or other killing agents appears to be economically impractical.

Chang (1949) has also found that simple shifts in the manner of the interplanting and fertilization of corn and sweet potatoes can materially reduce the exposure to infection among the agricultural workers tilling these plants.

**SHOES.** The wearing of shoes or any impervious covering for the feet will prevent the entrance of the larvae through these extremities. However, even when economically feasible it is difficult to keep shoes on children in the tropics or during the warm weather in the south. In the case of agricultural workers, in such crops as sweet potatoes, protection should be provided for the hands as well. Certainly the protection of the feet, as well as other parts of the body, should be encouraged but the limitations should be appreciated.

**EDUCATION.** The necessity for education to implement any control program cannot be too often emphasized. Such education can be accomplished through schools, in community meetings, and by the distribution of simple literature. The plans of the Georgia Health Department (Andrews, 1942) developed and put into operation before World War II, centered around the family unit. The hookworm families were discovered by routine surveys, commonly surveys in the schools, and some contacts made where children were found passing more than 5,000 eggs per gram of feces. An anthelmintic (tetrachlorethylene) and an iron supplement (Blaud's pills) were provided, and the underlying causes of the disease were discussed. Advice was offered on dietary improvement and stress was placed on sanitary disposal of feces. Assistance was offered in the construction of a simple but effective privy.

In the past 35 years, the amount of hookworm disease in the United States has been reduced. It is difficult to evaluate the specific factors involved but it seems evident that education has been a significant factor, and that recurrent treatment has had an educational value, at least, and that some economic improvement has helped in the improvement of sanitation both through private and public means.



The scope of the problem is constantly narrowing and concentration on the family unit is more and more indicated.

**PREVENTION AND CONTROL OF CREEPING ERUPTION.** Since this condition is caused by the penetration of the dog and cat hookworm, *Ancylostoma braziliense*, the disease may be prevented by not bringing the skin in contact with soil on which dogs and cats have defecated. This may be difficult to completely avoid in the case of children or with certain workmen, such as plumbers working under houses. Keeping dogs and cats from areas where children play is of very definite value. Attempts have been made in Florida, where the disease is common, to exclude dogs and cats from beaches. Treatment of household pets should prove to be of value.

### ASCARIASIS

The large roundworm, *Ascaris lumbricoides*, is widely distributed in the tropics and subtropics. It is probably the most common cause of worm infections of man in the tropics. Its distribution overlaps that of hookworm but often the areas in which it is most common are relatively free of hookworms. Although it is found in all age groups it is usually most common in children. In the United States it is most common in the eastern mountain areas from West Virginia southward (Otto and Cort, 1934).

**The Worm and its Life Cycle.** The adult worms (males 6 to 8 inches; females 9 to 15 inches long) live in the small intestine. They do not have any structures for attachment but feed upon the intestinal contents and hold themselves in position by lying U-shaped or even C-shaped and exerting a spring-like pressure against the intestinal wall. They are more prolific than the hookworms; the female lays about 200,000 eggs per day. The eggs are discharged in the feces in the one-cell stage and require not less than two weeks to become fully embryonated; it may take over a month for this process. They do not normally hatch until they are ingested. The newly hatched larvae are unable to develop in the intestine until they have completed a migration via the blood stream to the lungs, through alveoli and up the trachea to be reswallowed. About two months are required from the time the embryonated eggs are ingested until the worms have matured and eggs from them are discharged into the feces. The adult worms probably have a maximum life of less than a year and most of them are lost in less than six months.

**Pathology and Clinical Manifestations.** There is no well-defined clinical manifestation from which the presence of these worms may be suspected. The presence of the worms, therefore, can be routinely determined only by finding the eggs in the feces, either the normal one-celled eggs or unfertilized eggs; the latter will be found exclusively when solitary females have developed, or in other light infections. The worms may be seen with the fluoroscope following a barium meal. Since the eggs are so easily detected this has only limited clinical value and is of no significance in routine surveys.

The young worms undoubtedly damage the lungs during the pulmonary migration but unless there is massive invasion at one time there are no marked clinical manifestations. The adult worms may produce serious mechanical injury by perforations. Such damage appears to be most common when they are hyperactive due to fever, usually of some other origin, or due to chemical stimulation by ether or some other volatile anesthetic. Masses of the worms may produce blockage in the

all intestine or elsewhere in the alimentary tract. The only consistent systemic action is the development of an allergic reaction; commonly there is a history of old but recurring asthma (Keller and others, 1931).

**Transmission of the Infection.** *Ascaris* eggs are apparently the most resistant of the eggs and cysts of the parasitic worms and protozoa. Unfortunately, the tendency to cite the extreme survival time of the embryonated eggs has had misleading epidemiological implications. It is true that when *ascaris* eggs are maintained in water in the refrigerator a few will survive five years or more. However, even under these conditions most of them are dead within a much shorter period of time and when they are maintained at room temperature they scarcely survive a year in clean water. When oxygen tension is reduced chemically or biologically death is more rapid. They cannot develop at temperatures above  $37^{\circ}\text{C}$  and usually die in less than a week at this temperature; they are killed in less than an hour by temperatures above  $50^{\circ}\text{C}$ . They are quickly killed by sunlight or by desiccation. However, they will survive for months on the surface of soil if either subsurface moisture or a high atmosphere moisture, above 80 per cent relative humidity, is sufficient to prevent complete drying. Fecal plants on various types of soil in the endemic areas of Panama and the southern United States have shown that the eggs are destroyed in a few days in the sun but will survive for months in the shade.

Thus, the resistance of some of the eggs permits rather wide distribution in the endemic areas but heavy infections are maintained where there is close contact with soil on which there is continuous deposition of feces. Since there is no free-living larval stage, loose sandy soils are unnecessary, indeed may even permit the washing of eggs beneath the surface out of contact with man. Since the embryonated eggs must be ingested, defecation sites some distance from the house reduce the hazards of infection with these worms, whereas they may be the main source of infection with hookworms. It is dooryard pollution alone which permits continuous heavy infection (Brown, 1937). To a very appreciable degree the prevalence rate of *ascaris* may be taken as a direct index of the degree of insanitation. A high rate in children indicates that they play more or less continuously where they defecate. Casual eating or otherwise bringing contaminated hands to the mouth in such situations provides the optimum conditions for infection. In the United States, and much of the world, the family is the unit of infection with children playing the major role in transmission. Other units are mental hospitals and orphanages.

The use of night soil as fertilizer may help spread the infection where this practice exists but it is unlikely to build a heavy focus of infection alone. Even in China, where night soil is almost universally used for fertilizer, the *ascaris* infection is largely concentrated in those families with young children who regularly defecate in the dooryard.

**Prevention and Control.** As with any feces-borne disease, control is directed to the prevention of contamination of food or drink by feces. With this infection it is not fresh feces, but rather the eggs remaining and which have developed after most other evidences of feces have disappeared which are of concern. The general concepts of cleanliness in preparation and handling of food and drink and in consuming them need not be repeated.

The attack on the endemic source of the problem is through the slow process of education to bring about proper fecal disposal. Where night soil is used for fertilizer,



storage will destroy many eggs. Apparently most of them are destroyed in less than a month but under some conditions, particularly in cooler weather, they may survive for a longer time. Winfield (1934) has utilized ascaris eggs as an index of the effectiveness of storage methods; when ascaris eggs have died one may be sure that the eggs or cysts of the more severe pathogens, i.e., hookworms and *E. histolytica* have long since died.

Although the simple piperazine salts as well as hexylresorcinol are effective against ascaris, therapy has no demonstrated value as a public health measure (Otto, 1930).

### TRICHURIASIS

The whipworm, *Trichuris trichiura*, has a life cycle very similar to that of ascaris but differs in a number of details. It is a much smaller worm, it lives in the cecum, and the long whip-like anterior end is sewed superficially into the mucosa. There is no migration outside of the alimentary tract, the larvae, which hatch from embryonated eggs which have been ingested, apparently grow and undergo their several moults in the cecum. The adult worms live several years, apparently commonly as much as 5 to 10 years. They lay very few eggs per day compared to ascaris and hookworms; it is variously estimated from 1,000 to 3,000. The eggs are passed in the one-cell stage and require about a month to become embryonated. The eggs are much less resistant to drying than are the ascaris eggs so that the worms have a much more limited distribution. *Trichuris*, like ascaris, is common only when children or adults live, play, and eat on soil where fecal contamination takes place. However, *Trichuris* flourishes only where high ground water, heavy rains or some other source of water maintain a very moist soil (Spindler, 1929). It is particularly common in some mental hospitals. Outside of such institutions it is commonly found in southern Louisiana and to a more limited extent in the mountains of southeastern United States.

Their possible relationship to disease is not clearly established (Otto, 1935).

Prevention and control is essentially the same as for ascaris. No effective treatment is known.

### STRONGYLOIDIASIS

*Strongyloides stercoralis* is a small worm which lives partially burrowed superficially in the mucosa of the small intestine. Normally, the eggs laid by the female develop and hatch as they pass down the alimentary tract so that first-stage (rhabditiform) larvae are passed in the feces. Under suitable environmental conditions infective (filariaform) larvae develop in two to five days. All the free-living stages are quickly killed by drying, reduced oxygen tension, and by temperatures materially above or below the optimum which is 70° to 85° F (Cordi and Otto, 1934). The susceptibility of the free-living stages to adverse environmental conditions is in part balanced by a short period of free-living life and the fact that in the interposition a free-living sexual generation may permit multiplication during free-living life. Infection is commonly found, then, only in the tropics and subtropics where ground water or rainfall provide a moist soil. In the United States this infection appears to be common only in south central Louisiana but is found to a limited extent elsewhere in the southeastern part of the country. Although a high prevalence rate is found only in limited areas, the infection is widely scattered in a few people. Apparently

infection may persist for decades, once it becomes established. Each worm, however, lives for only a short time, apparently a matter of months and appears to lay only a few hundred eggs. These facts, together with the poor survival of the free-living stages, lends support to the belief that autoinfection is common. Whether this is a process of internal reinfection or external reinfection due to poor personal hygiene is not clear. Because the egg production is so low the resulting first-stage larvae may be very sparse in the feces and difficult to demonstrate even by repeated examination. Only freshly passed feces should be examined.

Prevention and control are as with other feces-borne diseases. Treatment may be required if a persistent infection is troublesome. Gentian violet is the drug of choice.

### ENTEROBIASIS

The pinworm or seat worm, *Enterobius (Oxyuris) vermicularis*, is the most widely distributed of the worms infecting man. In some areas of the tropics its prevalence rivals that of ascaris. In most areas in the temperate zone it is much more common than all other worms combined. It occurs in all age groups but it is by far most common in young children. Over 50 per cent infection was discovered among children in a private day nursery in Washington, D. C. (Cram and Nolan, 1939). The adult worms live in the lumen of the cecum; when the female is ripe, i.e., full of eggs, she migrates to the anus where the eggs are discharged either through the perianal pore or by complete rupture.

Accordingly, eggs are not mixed in the feces, as is the case with other worms which lay their eggs within the alimentary tract; routine fecal examination is essentially useless in attempting to establish the presence of the infection. Since the worms usually make their egg-laying migration after the subject retires, diagnosis, in children at least, is most easily established by direct examination of the anal area one or three hours after retiring. Eggs may be collected by scraping the area with the sticky surface of Scotch tape in the morning before there is any bowel movement. The Scotch tape should be immediately stuck smoothly to a glass slide, thus binding the eggs for subsequent microscopic examination.

Some of the eggs may be completely embryonated when laid, while others may require up to eight hours additional time for embryonation. The shells have a cement-like substance with which they become stuck to the mucous membrane, skin, hair, or clothes. Infection results from ingesting the embryonated eggs which hatch in the small intestine; the larval stages grow and undergo a series of moults, probably four, as they make their way to the cecum. The entire life cycle may be completed in less than a month so that reinfection alone accounts for the persisting infection in a given individual. Internal auto-reinfection has been invoked to explain persisting infections but there is no direct support for this postulate and it disregards the obvious opportunities for anus to mouth reinfection. The eggs apparently survive only a short period of time and while they have been recovered from dust in various rooms, even public school rooms, most of those so recovered are dead. This may represent one means of the dissemination of infection but much more intimate contact is required for rapid spread. Thus, it is common in orphanages and mental hospitals but passes equally as well within a family. It is no respecter of economic status or the usual concepts of personal cleanliness. Once a child in a family be-



comes infected, the infection spreads rapidly to other children and to any adult, as the mother, who is in close attendance upon the children. Not infrequently all members of the household become infected. It may be referred to primarily as an intramural infection. It is not clear whether changes in habits of personal hygiene or the development of an immunity keeps the infection rate down in adults; perhaps both are operative. The fact that the mother commonly becomes infected from her small children is suggestive. Prevention, treatment, and control are almost inseparable. It is useless to treat one member of a family at a time (D'Antoni and Sawitz, 1940). Treatment should cover not less than 10 days to reach all stages of development and preferably should be repeated after a week's rest. All members of the household should be treated at the same time and special precautions should be taken during this period with diapers, underclothing, night clothing and bed clothing to see that they are promptly washed. Extra precaution in the washing of hands, particularly those of children, should be stressed during this period. Piperazine citrate and piperazine adipate, which are also effective against ascariasis (Brown, 1954), are the drugs of choice.

The most common complaint resulting from pinworms is anal pruritis and this may be very troublesome. Fortunately, most individuals harbor the infection without any demonstrable sign (Weller and Sorenson, 1941). Perhaps the greatest significance of this infection is the evidence it affords of the extent to which feces reach the mouth under *good sanitary* conditions. This should be considered carefully before invoking the fly or the infected food handler as the source of any enteric infection, particularly the parasitic infections such as amebiasis.

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# 4

## CONTAGIOUS DISEASES SPREAD BY GENITAL CONTACT

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As a danger to the public health, as a peril to the family, as a menace to the vitality, health and physical progress of the race, the venereal diseases have been regarded as among the greatest of modern plagues and their control a most stressing problem of preventive medicine. Great strides have been made toward the solution of this problem but much remains to be done.

This group comprises five diseases—syphilis, gonorrhea, chancroid, lymphogranuloma venereum and granuloma inguinale—linked not because of similarity of causative agents, tissue reactions or symptoms produced but because the principal means of spread of each disease is by sexual intercourse, especially promiscuous sexual intercourse, as implied by their group name, “venereal.”

In spite of a comprehensive analysis of the importance of venereal diseases to the public health in 1876 by J. Marion Sims in his Presidential Address before the American Medical Association and his appeal for action on the part of boards of health, little was done until about 1912 (Parran, 1937). In this year the New York City Board of Health determined to treat the venereal diseases as any other highly communicable and infectious disease, dealing objectively with the hygienic factors of the problem from a public health standpoint. Similar action was taken by Montclair, New Jersey, in 1913. In the same year, the venereal diseases were made reportable by statute in Iowa, Kansas, Louisiana and Vermont. In 1914, Massachusetts began a control program based on early diagnosis and free treatment.

The advances made during World War I as a result of the Chamberlain-Kahn Act of July 9, 1918, establishing the Venereal Disease Division of the United States Public Health Service (Vonderlehr and Heller, 1946), were largely dissipated during the “back-to-normalcy” postwar period. Federal funds for venereal disease control dwindled from one million dollars per annum at the first year of the act to a mere one hundred thousand dollars in 1920. During the war and the 15 years following, a few states—notably Louisiana, Kansas, Montana, New Jersey, New York and Texas—established Divisions of Venereal Disease Control, and in some states these diseases were made mandatorially reportable by statute. Otherwise, venereal disease control remained quiescent until July, 1936, when Thomas Parran, then Surgeon General of the United States Public Health Service, blasted into the public’s consciousness again that the venereal diseases, especially syphilis and gonorrhea, were prevalent diseases which seriously menaced the public health. Modern venereal disease control began with his historic pronouncements.

Again the public was made aware that the venereal diseases are a constant menace to all classes of society unless everyone remains constantly alert. The history of preventive medicine can present no greater tragedy than the birth of a syphilitic child, nothing more pathetic than the newborn baby blinded by gonorrhea. Sadly enough, public health and medical measures alone do not suffice to allay such misadventures. The ultimate solutions to these problems transcend the use of medical and hygienic methods. The problems pervade law, education, social work, religion and economics. Ultimate control will depend upon the proper approaches undertaken and continued in each of these directions.

Measurable progress in venereal disease control has been made in the past 20 years, particularly in the field of education, case finding and treatment. However, we cannot avoid the conclusion that no matter how efficient diagnosis and treatment may be, the ultimate outcome to reduce these infections to an absolute minimum will depend upon the success in rendering cases noninfectious faster than the miscellaneous sexual relations spread them. More emphasis must be placed on coming spread of these diseases.

The venereal diseases are classified by state laws or regulations as syphilis, gonorrhea and chancroid. In addition, granuloma inguinale and lymphogranuloma venereum are reportable in some states. Syphilis and gonorrhea are of greatest importance because of their extensive prevalence and further because they are very serious infections with grave consequences. Gonorrhea has been characterized as the great preventer and syphilis as the great destroyer of life.

## SYPHILIS

Syphilis is a specific infection caused by the *Treponema pallidum*.<sup>\*</sup> It is acquired by intimate contact with infectious persons, with moist contaminated articles, and by congenital transmission. The initial lesion or chancre forms in the skin or mucous membrane at the site of entrance of the spirochetes. Syphilis runs a chronic course with lesions and symptoms of extraordinary diversity. It mimics many other diseases.

There are many striking things about syphilis, but nothing so striking as its persistence in spite of knowledge complete enough to almost stamp it out. Syphilis causes more mental and physical suffering than the other diseases of this category. It is preventable, even curable but these characteristics require that constant vigilance and control facilities be maintained.

Syphilis is a good illustration of the fact that it is much more difficult to control a disease transmitted directly from man to man than a disease transmitted by an intermediate host, or one in which infection comes directly from our environment. We have a certain amount of control over our surroundings and dominion over the lower animals, but the control of man requires the consent of the governed.

Civilization and syphilization have been close companions. Civilization must not be content until it has controlled syphilis as effectively as it has some other preventable infections. The effort must be persistent and in keeping with the need.

Economically, syphilis is not disabling in its primary and secondary stages. Persons in the early stages of the disease usually are not ill enough to cease work. But

<sup>\*</sup> First described by Schaudinn and Hoffmann in 1905 and called by them *Spirochaeta pallida*.



the infection is most communicable during this time. In the United States, 1 out of 10 cases are discovered during this stage. It is the late manifestations of acquired syphilis and all manifestations of congenital syphilis which endanger health and life. A considerable percentage of first admissions to the hospitals for the insane are due to syphilis. The estimated annual costs\* of uncontrolled syphilis are: 74,600 man years of disability (brain, heart, blindness); \$62,729,000 for maintenance (psychoses, blindness) and 115,830 man years loss of life expectancy.

The consequences of the disease are often more severe upon the offspring than upon the syphilitic parent. The infection is liable to be transmitted from parent to child and often with fatal results. If death does not ensue, the living consequences may be even more tragic.

The health officer should regard syphilis just as he does the other acute febrile exanthematous diseases. Because syphilis runs a slow and often chronic course, it is often placed in a class by itself. This is a mistake. Syphilis has its period of incubation, eruption and decline, just as measles and smallpox have.

**Historical Note.** There is an accurate historic record of the apparent spread of syphilis over the known world in a few years after 1495, and from that time it has everywhere become endemic. This is unique in epidemiology, for no similar record exists of the sudden establishment, if such it were, of a great disease among the larger part of the earth's inhabitants (Pusey, 1933; Hudson, 1946; Kemp, 1940).

Syphilis was not recognized as a clinical entity before the year 1493. It is said by some historians to have been brought by the crew of Columbus on his first voyage from Española, or Haiti. This is vigorously denied by others. The former insist that some of the returning crew accompanied Charles VIII of France in the autumn of 1494 with the army, 32,000 strong, which invaded Italy for the conquest of Naples. The "epidemic" began in Italy at this time and the disease spread quickly over Europe with the scattering of the troops. The French called it the Italian disease, and the Italians called it the French disease, or *morbus gallicus*. The present name of the disease was taken from a poem written by Fracastorius in 1530 entitled "Syphilis sive Morbus Gallicus," in which the symptoms are clearly described in the principal pastoral character, a swine-herd named Syphilus. The sexual nature of the infection was not recognized until some time after the "epidemic" outburst in 1494-1496. The history of the disease before this time is shrouded in difficulties and there is vigorous denial that syphilis was an American contribution to pathology.

\* V. D. Fact Sheet, December, 1954, Issue No. 11, U. S. Public Health Service.

† Sudhoff (Pusey, 1933) says that the story of the American origin of syphilis did not develop until almost a generation after the discovery of America and that it was first published in 1518 as an advertisement of the therapeutic value of guaiac introduced from San Domingo. He claims there was syphilis in Spain before Columbus' voyage and that it is quite possible some of the sailors had the disease. Moreover, he refutes the story of the terrible epidemic in the French army before Naples, and refers to the reports of Martino Sanuto, the Venetian Ambassador of Naples, which have been published in full. Virchow was unable to find lesions of syphilis in European and Oriental bones of the pre-Columbian age.

Bearing on the American origin of syphilis, according to Thom, bones from pre-Columbian graves offer evidence that syphilis existed among the aborigines before the Spaniards came to America. Williams considers that the evidence presented in a review of bones supposed to show syphilis, recovered during archeologic investigations, is sufficiently conclusive proof that syphilis originated in America. On the other hand, Hrdlicka found no authentic evidence of the disease in pre-Columbian skeletal material and concludes that the weight of evidence is against the American origin of syphilis. Nothing in either Indian tradition or Spanish writings

During the 200 years following this apparent outburst, much was learned about syphilis: signs and symptoms were recognized; its infectiousness proven; means of transmission were clarified; the duality of syphilis and gonorrhea were reaffirmed; lesions of congenital syphilis were described and treatment with mercury was widely used. In 1834, potassium iodide was introduced into the treatment of syphilis. Syphilis was differentiated from gonorrhea in 1852.

In 1903, Metchnikoff and Roux transmitted the disease to lower animals, demonstrated the prophylactic value of calomel injections, and also opened up a new field of animal experimentation. In 1905, Schaudinn discovered the *Treponema pallidum*, thus making diagnosis certain. In 1906, Wassermann, Neisser and Bruck introduced the Wassermann reaction. In 1909, Ehrlich, after many years of experiment, gave to the world salvarsan, a specific, synthetic spirocheticide, and opened the new science of chemotherapy. In 1911, Noguchi cultivated an organism resembling *Treponema pallidum*; and in 1913 demonstrated the spirochetes in the brain of a paralytic and in the cord of a tabetic.\* This unparalleled group of achievements, all the result of scientific work in laboratories, in 10 short years threw light on the cause, mode of transmission, pathology, treatment and prevention of the disease.

The history of chemotherapy for syphilis may be divided logically into three periods (Moore, 1945): (1) that of mercury, ending in 1909 with the discovery of 606 by Ehrlich; (2) that of arsphenamines, 1910 to 1943; and (3) that of the antibiotics beginning from the discovery of Mahoney and others (1943). Ehrlich's hope for a single curative dose of 606 was not realized partially because of serious toxicity of the drug. In 1917, Keidel and Moore in this country and Almquist in Scandinavia independently proposed a treatment plan embodying two new principles, the extension of treatment for longer than a year and the alternation of arsphenamine and a heavy metal (mercury at the beginning, in 1921 changed to bismuth). This has been the accepted method of treatment, both here and abroad, until recently. In 1933, a less toxic form of the arsenicals, arsenoxide, was reintroduced by Tatum and Cooper and in 1934 Chargin, Leifer and Hyman re-explored the effects of massive single dose arsenotherapy. The results were satisfactory but the increased risk to life was too great. As a result of these and other investigations, treatment schedules were developed based upon the researches of Eagle and Hogan whereby the complete therapeutic dose of mapharsen could be given in a period of 10 to 12 weeks with minimum toxic effects. The U. S. Army, using the information gained from these experiences, formulated a successful plan of complete therapy for early syphilis in a period of 26 weeks. These schedules were generally accepted in this country until the advent of penicillin in 1943. This is a new and powerful

at the time suggests the existence of the disease. Both Indians and Eskimos show a general lack of immunity when infected by Europeans.

Hudson (1946) presents further evidence against the theory of the Columbian origin. In view of the fact that pre-Columbian leprosy was considered highly contagious, was associated with sexual contact, had hereditary features and was said to be susceptible to mercury therapy, it is likely that the so-called leprosy of this period was actually syphilis since these are the characteristics of syphilis and not leprosy.

\* It is the general consensus among bacteriologists that successful cultivation of virulent *Treponema pallidum* has not been accomplished. Saprophytic spirochetes resembling it have been used in the picture.



addition to syphilotherapy. The evidence of 13 years of its use (1943 to 1956) is overwhelming as to its effectiveness, and as a weapon for public health control it is without parallel.

**Incidence, Prevalence and Trend.** The enormity of the syphilis problem has in recent years been brought forcibly to the attention of the medical profession and the general public. A most striking revelation of syphilis incidence for the country as a whole was brought to light by studies made by the United States Public Health Service and recorded by Vonderlehr and Usilton (1938). As a result of these studies, it was concluded that "syphilis strikes one in every ten adults." Although this statement is nondescriptive insofar as prevalence and the extent of the problem in limited areas are concerned, it emphasizes unquestionably that syphilis is a public health problem of major importance. This statement has been frequently misinterpreted to mean that 10 per cent of the population has syphilis. This is not the case. It means that if the syphilis attack rates for certain selected parts of the country were applied to the population of the country at large and these rates remained unchanged for a period of a lifetime, one out of every 10 persons might have been *expected to contract* syphilis before they reached the age of 50.

The actual *incidence* of syphilis, that is, the number of new cases occurring in a stated population during a specific time period, can only be roughly approximated. Such an approximation may be obtained in several ways: studies such as the one above (Vonderlehr and Usilton, 1938), "one-day surveys" (Parran and others, 1928), by notification of cases of early, i.e. primary and secondary, syphilis (U. S. Public Health Service, 1949), and by a calculation of discovery rates (Turner and others, 1943). The "one-day survey" seeks to provide information relating to prevalence as well as to incidence. In the chosen study area all treating agencies are asked to provide information concerning not only the number of persons under treatment and or observation on a given day (prevalence data) but also the number seeking diagnosis or treatment for the first time during a stated period of 30 days (incidence data). Such studies have not been carried out in recent years and as a result our present information on incidence and trend has been based almost entirely on the cases of primary and secondary syphilis reported to health agencies.

Such reported cases provide a measure of discovery, not of incidence. It is difficult to secure reliable information concerning the actual number of new infections which occur each year and equally as difficult to estimate the relationship of discovered to undiscovered cases. The occurrence of syphilis may remain constant or actually decrease in the face of an increasing rate based upon notification. The ratio of the discovered to the undiscovered depends upon the extent of venereal disease control practices, the degree of public enlightenment and interest, the availability of clinical facilities, the quality of syphilologic practice and perhaps many other factors. These vary from year to year and from locality to locality.

For the United States as a whole the rate of reported primary and secondary syphilis has varied from a high in 1947 of 75.6 to a low of 4.9 per 100,000 population (U. S. P. H. S., 1954). In every year during this period the number of early latent cases has exceeded that of primary and secondary cases. Therefore, we are compelled to assume that more than one-half of the cases of syphilis go into the latent stage undiscovered and unreported. The United States Public Health Service

imates that there occurred in the 48 states in 1954, 86,800 fresh syphilitic infections, 79,112 of which remain undiscovered.

**Prevalence.** The total number of cases of the disease existing in a specified area at any point of time, has been studied widely during the past few years. Such studies of prevalence have been based on serologic surveys of one or another kind upon "one-day surveys." Serologic surveys may be roughly classified into three groups: (a) those performed because of some medical abnormality (hospitals, clinics, doctors' offices); (b) those done on persons chosen on the basis of some social, economic or occupational grouping (food handlers, prisoners, blood donors, Selective Service registrants, college students); and (c) those performed on groups thought to be representative examples of specific communities. Studies of these three groups have shown prevalence rates to range from: group (a), 2.7 per cent among white females in a private practice in New York State to 49.4 per cent among Negro males in a private practice in Alabama; group (b), 0.2 per cent among white male students in college to 15 per cent among Negro applicants for marriage certificates in Virginia; group (c), 1.2 per cent among an unselected group of white males in Gibson County, Tennessee, to 23.6 per cent among Negroes in a serologic survey in Mississippi. One of the most significant presentations of prevalence in recent years has been the prevalence rates by color, age and residence per 1,000 subjects and volunteers examined in 1941. This is shown in Table 4-1 (U. S. Public Health Service, 1949).

Table 4-1. Syphilis detected in Selective Service examinations. Prevalence rate per 1,000 tested; age group 21-25

Age Group	White	Non-White	Total
21-25	10.1	191.2	30.1
26-30	20.9	293.7	54.4
31-35	37.7	357.2	85.2
ALL AGES	17.4	252.3	45.3

Prevalence and incidence studies throughout the country have, in general, shown that the rates among Negroes are higher than those among whites of comparable age, sex and economic groups. Among whites, the male rates are higher than those for females. Among Negroes, the total male rates equal those of females but there are some variations according to age. Females acquire their disease at an earlier age than males. Incidence is higher in the young, prevalence in the older, because of the effect of accumulation.

Measurement of the *trend* of syphilis, that is, the change in frequency from one time to another, involves all of the difficulties of measurement of incidence and prevalence and more, since changes in method of public health attack or actually in the definition of what constitutes a case of syphilis (presence or absence of positive tests, symptoms, lesions, etc.) may influence the calculated rate without reflecting actual change from time to time. It is generally agreed that the trend of syphilis is downward. There are those who believe that the newer treatment methods now in use are responsible for this and they foresee a continued and accelerated decline to the point where the disease will no longer be a problem. Others (Moore, 1951), although supporting the claims of decline, present evidence that this may be part



of a world-wide decline apparent since the middle of the nineteenth century, continuing since, and probably accelerated by modern control methods. There has been a tremendous decline in reported cases of primary and secondary, less marked in early latent and some in late, late latent and congenital syphilis since 1947 (see Table 4-2, page 284). Further evidence of decline is presented by Vonderlehr and Usilton (1943) after an analysis of data in a manner similar to their "one in ten study" of 1938. The chance of acquiring syphilis had dropped from 1 in 10 to 1 in 15. For analyses on a much smaller scale, Leiby and others (1947) suggest the use of prevalence rates among parturient women as an indication of trend. Turner and others (1943), searching for methods of measuring trend, found evidence that age-specific discovery rates among young adults (15-24) furnished a method which seemed promising.

**Mortality.** The actual syphilis death rate is unknown, not only because of the general disinclination of physicians to report syphilis as a cause of death, but also because the disease is so frequently masked in the general mortality statistics. If it be remembered that syphilis is the real cause of death in all cases of general paresis, locomotor ataxia, and aortic aneurysm, and in many cases of apoplexy, and is a contributory cause of death in a host of other conditions, including pulmonary tuberculosis, the real influence of syphilis on the general mortality rate may in some measure be appreciated. The extent of under-reporting deaths can be judged from a study by Nicoll and Bellows (1934). A confidential inquiry revealed that syphilis was stated on the original death certificate as a primary or contributory cause of death in approximately 49 per cent of cases in which it should have been so certified. The varying rates noted in the medical literature are essentially estimates modified by the personal bias and experience of individual observers.

"The sixth revision of the International Lists of Causes of Death," which became effective in 1949, reduced reported syphilis deaths by about 26 per cent. Rates adjusted according to the sixth revision show a decline from 11.1 per 100,000 in 1939 to 3.4 per 100,000 in 1953. These data give no indication of the differences that exist between the rates for the white and the non-white. These death rates fell steadily between 1939 and 1953: for whites, 7.7 to 2.5 and for non-white, 40.8 to 11.3 per 100,000 population. In 1945, 1 per cent of the total deaths from all causes were due to syphilis; of the white deaths, 0.72 per cent, of the non-white, 3.08 per cent (Kahn and Iskrant, 1948).

McCulloch (1930) in a review of 1,675 autopsies during the period 1909 to 1929, found that coronary sclerosis, angina pectoris, coronary thrombosis and myocardial infarction occur more often in the syphilitic than in the nonsyphilitic. In a series of 224 cases of chronic aortic disease reported by Cowan and Faulds (1929) syphilis was apparently the cause in approximately one third of the cases. In a series of 390 cases presenting macroscopic signs of cardiovascular disease, 60.3 per cent were syphilitic.

The well-studied autopsy material of the Yale University School of Medicine was reported by Rosahn and Black-Shaffer in a series of papers during the period 1943-1946 (Rosahn, 1947). The review of the world literature by these authors revealed that of 146,767 reported autopsies, 5.45 per cent were observed to be syphilitic at autopsy. The Yale material comprised 3,901 autopsies on persons over

years of age of which 390 or 9.7 per cent presented clinical, laboratory or autopsy evidence of syphilis infection. Of these, 390 individuals known to be syphilitic, treated and untreated, 23.7 per cent showed anatomic lesions of syphilis which were thought to have been the cause of death.

**Syphilis and Life Insurance.** Although the life insurance companies have taken an indefinite stand with respect to the insurability of syphilitics, the studies upon which this decision is based are inaccurate to an undeterminable extent. Schamberg (1945) reviews the literature on the prognosis of syphilis and concludes, "There is no evidence that syphilis adversely influences life expectancy except through the normal natural effect of its serious late manifestations, in particular those of the central nervous system and cardiovascular system." Heller and Bruyere (1946) conclude, after a study of a group of untreated syphilitic Negro males, that, "The life expectancy of a Negro man between the ages of 25 and 50 who is infected with syphilis and received no treatment for his infection is on the average *reduced* by about 20 per cent." Smith and Bruyere (1946), studying a group of treated syphilitics, conclude that, "The average life span of persons under routine therapy for syphilis is *shorter* than that of the uninfected person." Moore and Shamberg (1947) enumerate reasons why actuarial studies of the mortality of syphilis are incomplete, inaccurate and unsuitable for the determination of a policy in regard to the insurability of syphilitic persons, as follows: (a) known syphilitic populations are compared with supposedly nonsyphilitic populations, the latter of which contain an unknown proportion of syphilitics; (b) published mortality data do not take into consideration the prognosis of syphilis in the various stages, all types of syphilis infection being grouped together; (c) the exact mortality cannot be determined because of the inaccuracy of death certificates; (d) no consideration has been given to the fact that syphilis is primarily a disease of those in lower socio-economic groups which are subject to increased mortality risks from many other diseases; and (e) no consideration has been given to the adequacy of present-day treatment methods since the actuarial data that are available with respect to treatment relate to the preantibiotic era. This is a subject which requires much more careful study before a definitive answer can be given.

**Stages of the Disease.** Syphilis is divided into stages which are not well defined in time or sequence. The division is arbitrary, for there may be no sharp line of distinction and considerable overlapping is common. For example, while symptomatic neurosyphilis is usually one of the late manifestations it is occasionally observed early as acute syphilitic meningitis. In practice, the disease is classified as early syphilis and late syphilis.

*Early syphilis*, duration under four years, is subdivided into primary, secondary and early latent syphilis. *Late syphilis*, duration four years or more, is subdivided into latent syphilis, i.e., without clinical signs or laboratory manifestations except positive serologic test for syphilis, and late syphilis, including all the later manifestations of the disease, such as benign late (e.g., gumma of the skin and mucous membranes), visceral, cardiovascular, bone and joint syphilis, syphilis of the central nervous system (vascular, meningovascular, tabes dorsalis and general paralysis of the insane) and syphilis of the organs of special sense, particularly primary optic atrophy. Since invasion of the central nervous system usually takes place early in the course of the disease, asymptomatic neurosyphilis (positive cere-



prospinal fluid only) may be classified as early or late depending upon when the spinal fluid examination is performed. Congenital syphilis is similarly classified as early or late, the division being made at two years.

**THE CHANCRE.** The primary stage is the chancre, which appears within an average of about 21 days after exposure, forming at the site of entrance of the spirochete. The typical hunterian chancre \* is an indurated and indolent ulcer, usually single and painless. We now know, however, that it is frequently atypical and may be but a trifling lesion. In the absence of a careful inspection, the chancre may exist many days before it is detected, or even escape notice altogether. In the female the primary lesion is often located within the genital tract, is mistaken for an erosion and its true nature not recognized. Moreover, chancre on the external genitalia of the female is frequently inconspicuous and indurated but slightly if at all.

*Extragenital infection* is by no means rare. Unusual location of the chancre diverts suspicion which would be aroused by a sore on the genitals.

*Generalized infection becomes fully established even before the appearance of the chancre.* It has been proved by animal experimentation that the spirochete can penetrate the unbroken mucous membrane of the rabbit and be found within the adjacent lymph glands within 24 hours after inoculation: this in marked contrast to the slowness of the appearance of the chancre.

The chancre teems with *T. pallida* which may readily be seen with the darkfield illumination. This is the method of earliest diagnosis. The serologic reaction usually does not become positive until from several days to several weeks after the appearance of the chancre. It is important, therefore, to examine every genital sore by darkfield. The initial lesion of syphilis often resembles a chancroid, and sometimes may seem to be only a simple abrasion. Mixed infections frequently occur. The primary lesion of syphilis usually disappears spontaneously without treatment before the disappearance of the secondary lesion, or may persist throughout the secondary phase.

*Secondary Stage.* The secondary manifestations usually begin from four to six weeks after the appearance of the chancre but may be delayed for a year or more. The symptoms are generalized or localized eruptions on the skin and mucous membranes, enlargement of the lymph nodes, and alopecia; slight fever, headache, vague pains in the bones and joints and sore throat are also common constitutional symptoms. In a large number of cases these manifestations are so mild they escape notice altogether, or may never occur at all. When they do occur, they persist for a variable period of time (from a few days to several months) and, in turn, disappear spontaneously without treatment.

These early lesions of primary and secondary syphilis are characterized by relatively mild tissue reactions and by the presence of numerous *T. pallida*. The lesions are superficial, tissue is not destroyed, and healing occurs usually without scarring. With healing, the organisms disappear from the skin and mucous surfaces.

\* John Hunter accidentally inoculated himself and purposely delayed treatment in order to study the disease in his own person. He accurately described the initial sore which has since been called the hunterian chancre. He differentiated syphilis from chancroid, but confused it with gonorrhea in 1786. Ricord in 1838 wrote a memorable treatise overthrowing Hunter's mistaken ideas and established gonorrhea and syphilis as separate diseases.

**LATENCY.** Upon the spontaneous healing of the early manifestations, there ensues a period of unpredictable length during which there are no outward signs of syphilis and during which the infected individual is recognized as syphilitic only by means of positive blood serologic tests. This period of latency may persist for a few months or it may be prolonged throughout life. The apparent symbiotic relationship between the invading organism on the one hand and the infected host on the other may be interrupted during the first few years of infection by one or more periods of spirochetal aggressiveness resulting in infectious relapsing lesions of the skin or mucous membranes. These relapsing lesions are characterized by their clinical similarity to those of secondary syphilis and are highly infectious. After the first few years this clinically latent relationship between organism and host may be interrupted by progression of the disease in the skin, cardiovascular system, bone, joints, viscera and central nervous system resulting in the well known manifestations of this disease.

**LATE SYPHILIS.** This stage or period is subject to all manner of variations, from clinical latency to symptomatic late syphilis, a fact that causes this disease to be called "the great imitator." The term latency refers to clinical latency, that is, the absence of outward manifestations of the disease. During this variable period, one of three immediately undetectable phenomena may be taking place beneath the surface. One is a complete triumph for the human host—the disappearance of all anatomic and bacteriologic evidence of infection—so that at autopsy, when the patient finally dies from some other cause, all evidence of syphilis is absent. In another, the reaction of the host to the organism may be considerably altered, the tissues developing the capacity to react in a manner totally different from that of the first few years. Instead of superficial, insignificant lesions rich in treponemes he may develop large, obdurate, destructive lesions which contain relatively few organisms, the gumma. Third, there may be a slowly progressive chronic inflammation in various tissues, particularly the cardiovascular and nervous systems, with subsequent fibrosis and ultimate impairment of physiologic function in these organs.

The gummas occur at varying time intervals following infection but are usually the first of the late manifestations to appear. The incubation period of symptomatic late syphilis varies with the type but, in general, clinical evidence of such involvement is more prominent in the second and third decades of the disease. Cardiovascular lesions become manifest even more slowly, their incidence reaching a peak usually in the third decade following infection. Any or all of these manifestations may be present in a single individual.

**Diagnosis.** *Early diagnosis followed by prompt and adequate treatment are the most practical and promising measures for the control of syphilis.* The clinical symptoms are often atypical and elusive, yet careful clinical examination combined with judicious use and interpretation of laboratory tests, will result in early diagnosis in the majority of instances.

**BY DARKFIELD EXAMINATION.** The lesions of early syphilis, rich in *Treponema pallidum*, provide the only means of *conclusive* diagnosis. Spirochetes in serum from the chancre, from the scarified skin lesions, from the mucous patches and condyloids of secondary syphilis, and in tissue juices aspirated from the satellite buboes of primary and secondary syphilis, can readily be seen under darkfield illumination. Because of the similarity of spirochetes normally found about the genitalia and in



the mouth, the identification of the true *T. pallida* should not be in the hands of the tyro. Many clinicians will not rely upon darkfield examination from mouth lesions done by the expert himself. Darkfield examination should be applied as a routine to every genital sore. A single negative finding is not conclusive and the examination should be repeated daily for several days. Local antiseptics should not be applied until the diagnosis is established for they may destroy the surface spirochetes. Bathing the lesion in simple salt solution enhances the probability of finding the organisms. The younger the lesion, the more readily are the spirochetes demonstrated. Puncture of the satellite bubo affords a simple means of early diagnosis when the examinations of chancre serum prove negative. The richest sources of *T. pallida* are the condylomata of secondary syphilis.

**BY EXAMINATION OF BLOOD SERUM.** The blood serologic tests become positive only after general invasion by the spirochetes has taken place. At the time of the first appearance of the chancre these tests are practically always negative. In the great majority of instances, the test will become positive within the first 3 to 14 days following the appearance of the primary lesion, this time interval depending upon: (a) the appearance in the blood of "reagin" in sufficient amounts to be detected, and (b) the sensitivity of the serologic test being used. A single unsupported negative test is not sufficient to rule out syphilis, nor is a single unsupported positive test sufficient to make the diagnosis of the disease.

In spite of the fact that numerous serologists have given their names to the serodiagnostic tests for syphilis (Eagle, Kline, Kahn, Hinton, Mueller, Meineke, Laughlin, Ide, Mezzini, Chediak, Wassermann, Kolmer, Wadsworth and others) these tests are based upon a *single principle* and upon only *two basic procedures*. The numerous names represent modifications of these basic procedures. The underlying principle is related to the fact that there appears in the blood following syphilis infection (and following other infection, for that matter) an antibody-like substance called "reagin." This "reagin" has the property of combining with fine divided particles of mammalian tissue, particularly beef heart (the antigen). The two basic procedures are devised to determine whether or not such a combination has taken place and are known as *complement fixation* and *flocculation or precipitation*. All of the serologic tests for syphilis are modifications of one or the other of these detecting procedures. Not only do these tests vary tremendously in sensitivity and specificity but also the individual tests may vary in performance from day to day.

In view of the nonspecificity of the antigen used in the performance of the tests, it is not at all surprising that false-positive reactions are frequently encountered. Among the diseases and conditions that have been shown to produce false-positive reactions with these tests are the following: infectious mononucleosis, malaria, leprosy, vaccinia, upper respiratory infection, chancroid, lymphogranuloma venereum and others. False-positives may also be technical ones or may result from the fact that a certain number of normal individuals have this antibody-like substance circulating in their blood.

After the widespread use of quantitation (titration) of reagin, which was an essential adjunct to control and to the evaluation of treatment, the most significant advance in diagnosis has been the development of the treponemal immobilization test (TPI). The specificity of this test makes it useful in distinguishing biologic false reactors.

**BY EXAMINATION OF THE CEREBROSPINAL FLUID.** Invasion of the central nervous system takes place early in the course of the disease and can be detected by examination of the cerebrospinal fluid many years before involvement occurs. The examination should be performed for every patient infected with the disease and could consist of a cell count, a determination of total protein, performance of the colloidal gold test, and a quantitative complement-fixation test.

**Methods of Transmission.** Transmission of syphilis depends: (a) upon satisfying the biologic requirements of the organism; (b) upon certain conditions of the host-parasite relationship; and (c) certain habits and customs of people.

The biologic requirements of the *T. pallidum* explain why syphilis is a disease of intimate contact (Clark, 1948). This organism is a very fragile one, unable to resist drying, unfavorably affected by many common agents, and is said to be killed by the weakest antiseptics and to be killed more quickly by soap solution than by many strong disinfectants. It dies under blood bank conditions in 72 hours but will survive rapid freezing to  $-76^{\circ}\text{C}$  for a year. It has been found inactive for 26 hours in syphilitic autopsy material. It is immobilized at  $41^{\circ}\text{C}$  ( $105.6^{\circ}\text{F}$ ) in two hours. These facts have a direct bearing upon the behavior of the organism in nature. Only on the mucous membranes about the genitalia and the mouth are conditions consistently found in man which permit its survival for periods long enough for invasion.

As stated by Stokes and others (1944), "It is not a divine moral purpose, or a satanic punitive ingenuity that connects syphilis with genital activities, but a mere biological accident no more significant in the last analysis than the fact that potatoes grow in sandy loam."

The host-parasite relationship (Clark, 1948) must be such that: (1) it is possible for the organism to *escape* from the infected host in sufficient numbers; (2) the organism must be appropriately *transmitted* under conditions which satisfy its biologic requirements; and (3) it must gain *access* by finding appropriate portals of entry in the new host. Moist surfaces provide the avenues by which the organisms escape from their reservoir, and intimate contact by sexual intercourse or kissing furnishes the conditions necessary for conveyance to a corresponding portal of entry in a new host. The newly implanted micro-organism becomes established under conditions of moisture, warmth and low oxygen tension and may penetrate intact mucous membrane.

Moist infectious lesions are present only during primary, secondary and recurrent secondary syphilis. Body fluids and secretions (saliva, semen, usual common vaginal discharges) from syphilitics in various stages of the disease have been studied experimentally and frequently have been shown to contain the organisms during the early stages of syphilis when lesions are present, but only rarely during the later stages when there are no obvious lesions. Blood has been shown to be infective chiefly during the incubation period and while primary and secondary lesions are present. Transfusion syphilis has resulted from the use of donors with early lesions or in the period before their occurrence or immediately after their disappearance. The usual explanation of *in utero* infection at the present time is that occasional spirochetemia occurs and results in the placental transfer of organisms to the fetus. This has not been proven experimentally.

Intimate contact with primary and secondary lesions provides the most favor-



able conditions necessary for transmission. However, despite the presence of infectious lesions, transmission following unprotected sexual exposure does not invariably take place.

Klingbeil and Clark (Clark, 1948) found that 18 of 97 marital partners (18 per cent) escaped infection although they were exposed sexually to early infectious lesions. Other studies of conjugal syphilis have contributed to the knowledge of transmissibility. O'Leary and Williams found no instance of conjugal infection among spouses of 25 patients (13 untreated) who had acquired syphilis four or more years before marriage.

Paternal transmission of syphilis direct to a fetus does not occur. Congenital syphilis is a result of maternal infection. Thus Colles' Law, concerning nonsyphilitic women and their syphilitic offspring, and Profeta's Law, concerning syphilitic women and their nonsyphilitic offspring, have no place in modern syphilology.

Under certain conditions the syphilitic pregnant woman can transmit syphilis to the fetus in utero after, but not before, the fourth month of pregnancy. Cellular as well as humoral factors within the host are thought to be responsible for this. Transmission to the fetus depends upon the duration of infection in the mother, the number of previous pregnancies and the amount and type of treatment received. A child of a treated or untreated syphilitic mother may be born: (1) *nonsyphilitic* with a negative serologic test or a positive test which becomes negative in a short time; (2) *syphilitic* with a negative or positive serologic test and no signs of the disease until several weeks after birth; (3) *syphilitic* with a positive test and with signs of the disease at the time of delivery; or (4) *dead* as a result of syphilitic infection.

Transmissibility, therefore, depends upon: (1) the duration of infection; (2) the presence of moist lesions; (3) the infectiousness of secretions; (4) tissue reservoirs of organisms; (5) intimate contact with the organism in sufficient number; and (6) accessible portals of entry in the susceptible individual which satisfy the biologic requirements of the organism.

The chance of exposure to any micro-organism is dependent upon habits and customs of the people in relation to that specific organism. This relationship in syphilis is such that sexual behavior and promiscuity of the population determine the transmission of the disease. High prevalence and high incidence rates usually are a reflection of high promiscuity rates since the frequency of infection varies directly with the frequency of exposure to the *T. pallidum*.

**Immunity.** There is no known natural immunity to syphilis in man. It is convenient to divide considerations of acquired immunity into two parts: (1) resistance or immunity of the infected individual to new organisms introduced from without, i.e., reinfection or superinfection; (2) resistance to the organisms already present in the tissues.

1. **RESISTANCE TO ORGANISMS FROM WITHOUT.** Experimental reinoculation of an already infected but untreated man or animal results usually in a lesion which takes the appearance of those present at the time of the reinoculation. If lesions have disappeared, no lesion at all ordinarily follows reinoculation. Immunity has been established.

When infected animals or human beings are treated, resistance to reinoculation is related to the time at which treatment is started. For example, reinoculation

bits treated before the forty-fifth day of their disease usually results in the development of a second chancre and if treatment is given between the forty-fifth and fiftieth day, a second chancre not infrequently results from reinoculation. If, however, treatment is deferred until after the ninetieth day (during the stage of latency) reinoculation does not usually result in a new infection. The immunity that has developed can be overcome by greatly increasing the size of the inoculum of a homologous strain or by using a heterologous strain.

2. RESISTANCE TO ORGANISMS WITHIN. There is no question that resistance to syphilitic infection actually does develop. This is demonstrated by the evolution of untreated disease when early lesions of primary and secondary syphilis heal spontaneously. In a short period of time, lesions which literally swarm with organisms have disappeared and the organisms remain in relatively small numbers in all organs. Thus, there is established an equilibrium between the organism and the defense mechanism of the host. This equilibrium may be turned in favor of either the host (spontaneous cure) or the parasite (infectious relapse in early syphilis or progression into late syphilis).

There is at this time no unanimity of opinion among syphilologists regarding the criteria for differentiation between syphilitic relapse and reinfection. However, the previously held rigid standards for diagnosis of reinfection have been questioned in recent years as a result of observations on patients treated intensively. It is the consensus that reinfection occurs much more frequently than was thought to be the case 20 years ago.

Marriage and Syphilis. The state of Louisiana in 1954 became the forty-second state or territory to provide for the *premarital examination* for both bride and groom. Thus, most of the states and territories have case-finding and protective laws, leaving only eight states plus the District of Columbia, Puerto Rico and the Virgin Islands without protection. Forty-two states, Alaska, Hawaii and the Virgin Islands also protect babies from syphilis by laws providing for *prenatal blood tests*, the District of Columbia, Puerto Rico and six continental states still being without legislation (Public Health Service Publications Nos. 383 and 365).

Whether one supports this type of legislation or not, it cannot be denied that 500,000 tests—estimated by the Public Health Service to have been performed annually under these laws—serve in some measure to find cases, save lives and prevent disaster.

In general, these laws are devised to discover applicants for marriage who may have infectious or potentially infectious syphilis. In only one state (Missouri) is a laboratory report and an affidavit on the part of the applicant sufficient for the issuance of a license; some states permit marriage irrespective of the results of the laboratory test if the woman is pregnant (e.g., South Dakota); one state (Kansas) bars marriage (subject to appeal) of syphilitics; and in several states evidence of a negative test and examinations are required of each applicant. Four states require the State Health Department to grant permission for issuance in cases of applicants with positive serologic tests; three states (Virginia, Massachusetts and Montana) require only that the applicants be told by the physician that syphilis is present in one or more of the applicants and that the possible consequences of the disease be explained. In the remainder of the states having such laws, a license is



granted following a serologic test and a statement by the physician that the disease is not communicable or in a stage which might become communicable.

Because of the vagaries of this disease and the differences of opinion which exist in respect to the duration of its infectiousness, the premarital examination laws have been misinterpreted by physicians and applicants alike. In some instances certification has been refused on the basis of a positive blood reaction alone. It should be stated that the intent of these laws is not to prevent permanently the marriage of persons with syphilis but only to delay the marriage of those with communicable or potentially communicable syphilis until the disease has been rendered permanently noninfectious. Two objections are obvious: (a) that a bar to marriage is not a bar to sexual relationships, and (b) that it is difficult or impossible scientifically to state just when syphilis becomes noninfectious.

Under these laws, the physicians are required to answer two questions: (1) Does the candidate have syphilis? (2) If the candidate does have syphilis, is it infectious or potentially so? The answer to the first question lies in the judicial interpretation of standard diagnostic procedures: a full history, a careful clinical examination, darkfield examination, and confirmed or repeated serologic tests for syphilis. If all these procedures are carefully done and are found to be negative, it is safe to assume that the candidate does not have syphilis. It cannot be emphasized too frequently, however, that a negative blood reaction does not by itself rule out syphilis. As a matter of fact, the blood reaction may be negative in the presence of highly infectious syphilis (seronegative primary syphilis). Furthermore, there are many conditions other than syphilis which can occasionally give rise to positive blood tests. A single positive serologic reaction, unsupported by clinical evidence or history of syphilis, should not be interpreted as diagnostic of the disease but only as indication for more careful investigation.

After a diagnosis has been established, the laws of most of the states and, of course, good medical practice obligate the physicians to form an opinion as to whether or not the disease is communicable or potentially so. This judgment depends upon an understanding of the biologic course of the disease and the vehicles and conditions of its transmission (see above). In general, it can be said: (a) that the early lesions of syphilis are highly infectious; (b) early latent syphilis is potentially infectious; (c) syphilis of five or more years duration is probably not potentially infectious (except in utero); and (d) late syphilis is not infectious. Applicants with congenital syphilis may be certified provided it can be established that a reinfection has not taken place.

If the diagnosis of syphilis is established and if the applicant is considered to be in an infectious or potentially infectious stage, treatment should be instituted in the amount and type considered adequate for the particular treatment method utilized, before the physician can legally certify noncommunicability. The majority of the laws of this kind do not provide recommendations for the situation in which one applicant is found to have syphilis in a noncommunicable state or for the instance where both applicants are found to have the disease. In the first instance, although there may be no danger of transmission to the marital partner, there is the ultimate possible danger of progression of the disease, in the absence of adequate treatment. Central nervous system or cardiovascular system syphilis can bring serious

financial disaster to the family. In the second instance, it is not possible for the disease to be transmitted to the marital partner already infected, but there may be risk in such instances to the offspring of such a union.

**The Curability of Syphilis.** Cure in syphilis means: (1) that the patient becomes and remains symptomatically well; (2) that he is incapable of transmitting infection to others; and (3) that in addition he becomes and remains serologically negative as to blood and spinal fluid (Moore, 1943). Syphilis is a curable disease both therapeutically and spontaneously. The extent of spontaneous cure is a matter of conjecture, estimates varying between 10 and 30 per cent of those detected and untreated. Cure as a result of specific treatment depends upon the time of institution of treatment, and on the amount and type of the specific therapeutic agent. Cure may be interpreted as biologic, serologic or symptomatic. To the physician and the biologist, cure is interpreted in its biologic and serologic sense, that is, biologically the eradication of the last remaining spirochete, so that the patient, insofar as his syphilitic infection is concerned, is in the same state as before he acquired the disease. Serologic cure means the laboratory tests of the blood and spinal fluid become and remain negative. On the other hand, it is symptomatic cure which is of interest to the patient. This means that the patient becomes and remains well, so far as his syphilis is concerned, for the remainder of his lifetime. The patient wants the answer to the question, "What are my chances of becoming and remaining well with no further trouble from this disease?" This depends upon the adequacy of treatment and the patient's willingness to follow obediently the instructions of his physician. Under these circumstances at the present time the probability of cure approaches 100 per cent.

**Prevention.** Early diagnosis and prompt treatment are the most promising and practical measures to control syphilis. To accomplish this, education is fundamental. After reporting and the epidemiologic study of every case of early syphilis in order to find possible foci of infection and spread are feasible and have been shown in practice to control the spread of the infection and to disclose early cases which otherwise would be missed. Early diagnosis and prompt treatment are methods of preventing the spread of syphilis, but our duty in preventive medicine is to make every effort to prevent infection in the first place.

**Summary.** Despite great progress in control, syphilis today (1955) is an important health problem because so many cases are undetected during the early stages. It is primarily a disease of youth, but its effects are manifest in later life. Estimated annual costs of uncontrolled syphilis are: 74,600 man years of disability; 2,729,000 for maintenance of the syphilitic blind and mentally ill; \$108,558,000 loss of income and of state and federal income tax from patients with syphilitic diseases; and 115,830 man years loss of life expectancy. It lowers the standard of health and contributes enormously to lowered individual economic efficiency. It causes a large proportion of the abortions and miscarriages. It is a frequent cause of the disintegration of home ties and is a destroyer of happiness and the source of untold suffering. Nevertheless, it is largely a preventable and curable disease. It is one of the few diseases for which there is a specific remedy. It is preventable yet it continues to spread, due largely to the fact that it is acquired chiefly through sexual contact and, therefore, becomes a hidden disease. The control of syphilis is centered about early diagnosis, prompt treatment and the provision of adequate



diagnostic and treatment facilities; upon finding and treating foci of infection. The success of these measures depends upon education of the medical profession and the public.

### GONORRHEA

Next to measles, whooping cough, chickenpox and the common cold, it has been estimated that gonorrhea is the most prevalent of the acute infectious diseases (Top, 1947). Among the venereal diseases it is by far the most prevalent, occurring approximately six or seven times more frequently than syphilis. In fiscal 1954 there were reported to the United States Public Health Service 239,661 cases of gonorrhea as opposed to 7,688 cases of primary and secondary syphilis (U. S. Public Health Service, 1954).

Recent developments in the therapy of gonorrhea have created such conflicts of opinion among physicians and health officers as to pose questions such as, "Is gonorrhea control a public health function?" (Kiesselbach, 1949). This, in spite of its great incidence and in view of the fact that the complications of the disease *per se* have not changed.

Gonorrhea involves not only the infected person, but often the innocent also in tragic consequence. Married consorts infect each other, often resulting in disruption of the home and in the social calamities which follow; and in wage earners it causes loss of health and lowered efficiency. A high percentage of the cases of sterility in women is due to gonorrhea and much of the pathology coming to the attention of gynecologists is a consequence of this infection. One of the most calamitous sequelae to gonorrhea in the pregnant woman is the infection of the eyes of the baby at the time of birth. Ophthalmia neonatorum in the majority of instances is due to the gonococcus.

In any consideration of gonorrhea from the medical or the public health standpoint, the facts logically arrange themselves into four distinct categories: (a) gonorrhea in the male; (b) gonorrhea in the adult female; (c) gonorrheal vulvovaginitis in children; and (d) gonorrheal ophthalmia neonatorum (Nelson and Crain, 1938).

**Historical Note.** The story of the exact origin of the disease is unknown, but what appears to be gonorrhea is mentioned in the fifteenth chapter of the Book of Leviticus in terms of "a running issue out of his flesh." Hippocrates in 460 B.C. knew of the disease and Galen, a Greek physician, in 200 A.D. applied the name to the disease by which it has been known since. His belief was that the discharge was an involuntary flow of semen; hence the name (gonos, seed; rhoia, flow). Its relationship to sexual intercourse was not realized for many years, and it was the latter part of the nineteenth century when it became known and accepted as a communicable disease (Nelson and Crain, 1938). Although Hill distinguished syphilis from gonorrhea in 1790, the two diseases were immediately confused by the classic experiments of John Hunter. He "proved" that they were variations of the same disease by the demonstration of the development of syphilis following the inoculating of his skin with urethral discharge from a patient with gonorrhea. In view of our present knowledge, it is clear that the patient had either both gonorrhea and syphilis or that the urethral discharge was caused by a hidden urethral chancre and not by the *gonococcus*. It was not until 1831 that Ricord

nitely separated syphilis from gonorrhea and it was years later, in 1879, when Loeffler isolated the *gonococcus* and proved that it was the etiologic agent.

**Incidence, Prevalence and Trend.** The actual prevalence of gonorrhea in the general population of the United States is unknown and even approximations are difficult because of the amazingly indifferent attitude toward this disease in the general belief that it is seldom, if ever, attended by serious consequences. Many people consider that it is "no worse than an ordinary cold." The perfection of modern treatment has added to this misconception.

Notifications to state boards of health are indeterminate. There is great laxity in this respect due to the reluctance of physicians to report cases even though notification is required by law. During the five-year period 1950 to 1954, 1,303,602 cases of gonorrhea were reported to the United States Public Health Service in 48 states, comprising an annual average of 260,720 cases (United States Public Health Service, 1954). The most disturbing aspect of gonorrhea incidence is the high proportion of young people who acquire the disease. The highest rates are seen among the 20-24 age group (almost 1 per cent in 1953). Even more startling is the rate among teen agers. In 1953 this rate was 480 per 100,000 aged 15-19, or among every 200 teen agers in the United States.

**Diagnosis.** The diagnosis of gonorrhea is not easy. Microscopic examinations of urethral, vaginal or intracervical smears, showing Gram-negative diplococci, pairs and shaped like coffee beans, within the polymorphonuclear cells, even in the acute cases may not be gonococci. Unquestionable diagnosis can be made only by culture and the utilization of sugar reduction tests. The *gonococcus* alone ferments glucose, not maltose. The *gonococcus* belongs to the Neisserian group of organisms including the *N. meningococcus*, *N. catarrhalis*, *N. flava*, *N. sicca*, and *N. gonorrhoeae*. The individual species are usually differentiated by their respective abilities to ferment different sugars with the formation of acid, colony forms, growth requirements, and serologic reactions.

In acute urethritis of the adult male, accurate diagnosis is no longer a simple matter because other organisms are known to produce nongonorrheal urethritis. In the female, however, a great amount of patience must be expended sometimes before satisfactory bacteriologic proof is obtained. It is in these cases where the culture method has proved so valuable. The culture method found so practical is that described by Carpenter (1936).

The difficulties inherent in diagnosis of gonorrhea are demonstrated in a review by Kiesselbach (1949). Of 400 patients referred to a Rapid Treatment Center with a diagnosis of "gonorrhea," only 39.4 per cent were found to have gonorrhea when subjected to confirmation by culture and fermentation tests. Of 213 cases already diagnosed as gonorrhea on clinical and slide evidence by local health departments, only 46 per cent could be confirmed as actually having gonorrhea. Of a large number of girls between the ages of 11 and 18 admitted to a state reformatory, 80 per cent were found to have positive clinical and slide tests for "gonorrhea." A test of these individuals using the carbohydrate fermentation tests revealed none of them to be infected with this disease. A large general hospital in the South found, on routine vaginal examination of all infant females, that the great majority had clinical signs, and slide tests were positive for "gonorrhea." When carbohydrate fermentation tests were done, not one was found to be infected with this disease.



A venereal disease control officer of a New England state reported that between January and April of 1948, 50 per cent of the male patients coming to his central clinic with a urethral discharge were found by the laboratory to be nongonorrheal.

As long as such difficulties in diagnosis continue and as long as two thirds of those estimated to be infected each year do not come to medical attention, gonorrhea will continue to remain a public health problem.

**Transmission.** As in syphilis, transmission of gonorrhea depends upon: (a) satisfying the biologic requirements of the organism; (b) certain anatomical characteristics of the human host; and (c) the habits and customs of people. This is another micro-organism that requires moisture to live and thus has little vitality outside of the human host. And its transmission depends upon the interchange of moisture, directly or indirectly, from the infected to the uninfected host. Whether or not the micro-organism invades the new host depends upon the type of tissue upon which it is deposited. It does not penetrate the skin. Of the three types of epithelium found in the genital tract—stratified squamous, columnar and transitional—only the columnar and to some extent the transitional are susceptible to invasion by gonococci. Thus, invasion by the *gonococcus* takes place only in those tissues composed of columnar epithelium or of the transitional type. This limits the manifestations of gonorrhea to only a few places of the human body.

**Gonorrhea in the Male.** After an incubation period of three to nine days, a thick, yellow purulent discharge from the anterior urethra makes its appearance. Spread to the posterior urethra, the prostate and other parts of the body takes place after varying lengths of time. Although the disease is a self-limited one, complications occur, such as epididymitis, arthritis and prostatitis.

**Gonorrhea in the Adult Female.** The disease in the female is described as having three stages: the stage of initial infection, that of pelvic invasion, and the stage of pelvic degenerative changes.

The first stage begins a few days after exposure, usually less than a week, and is manifest in most cases by mild burning or smarting. Examination may reveal mild changes. In only occasional instances are these early signs and symptoms severe. The next stage, that of pelvic invasion, may be delayed until after the first or second menstrual period following infection. The first, and sometimes the only, signs that the disease has passed upward beyond the cervix is a menstrual period which begins too soon or lasts too long or the flow is unusually heavy. There are wide variations in these manifestations. There may be no evidence of extension. As the infection extends into the Fallopian tubes it causes salpingitis and frequently the pus produced in the tube spills into the pelvic cavity and acute pelvic peritonitis results. Symptoms may be mild or severe. This acute infection of the pelvic contents subsides after a short period but usually a chronic low-grade infection may persist for many years. The third stage is actually the aftermath of infection. It damages organs of reproduction and accounts for much "female trouble." It causes abdominal operations and is a cause of sterility. The mild early symptoms and the difficulties of diagnosis in females make gonorrhea in the female still a considerable health problem despite advances in treatment.

**Vulvovaginitis in Children.** This is an inflammatory process involving the urogenital tract in females, chiefly the vulva and vagina, characterized by swelling and redness of the mucous membranes and by purulent discharges of varying

ee. It may be caused by a variety of organisms, including the *gonococcus*. It is not strictly a venereal disease but its history was inseparably linked with gonorrhea until a few years ago. Among other contributions, that of the New York City Department of Health reported by Cohn (1942) showed that only a relatively small proportion of so-called "gonococcal" vaginitis (22.2 per cent of the latter cases) was due to infection with the *gonococcus*. It was found that smears were generally not reliable and that only cultures allowed a direct diagnosis. Of considerable interest was the fact that of the untreated group, 87 per cent became cured spontaneously by the twenty-eighth week after the beginning of observation. This tendency to spontaneous cure indicated that the infected tissue had the natural tendency to heal. Healing was not hastened by estrogenic therapy.

Discharges from infected persons provide the avenues of infection and the mode of communicability is determined by the presence of the causative agent in the discharges. Prevention depends basically on the control of gonorrhea in the population and specifically on proper supervision of institutions for children with and enforcement of hygienic principles. Isolation is recommended for the first 24 hours after the administration of antibiotics (American Public Health Association, 1955).

**Ophthalmia Neonatorum.** Ophthalmia neonatorum includes every type of purulent inflammation of the conjunctiva which occurs during the first three weeks of a baby's life. This is an acute infection caused by a variety of infectious agents. In the past a great majority of these infections was due to the *gonococcus*. At the present time the most frequent type of infection is inclusion blenorrhea, caused by virus. The offending organism usually gains access to the conjunctiva during birth as the baby's head descends through the infected birth canal of its mother. The incidence of gonorrheal ophthalmia neonatorum is difficult to determine at the present time, yet there is no doubt that there has been a remarkable reduction in the occurrence of this condition and its complication (especially ulceration of the cornea and blindness) since the introduction of the Crede silver nitrate method of prophylaxis (Top, 1947). This procedure, required by law in 44 states, is carried out as follows: clean eyes with cotton and boric acid solution, separate the lids and instill one to two drops of 1.0 per cent silver nitrate solution, taking care that the solution does not fall on eyelid or cheek. The solution is then washed out with saline after two minutes.

In spite of the success of this procedure in preventing blindness, there has been persistent criticism of the use of a strong corrosive in the eyes of the newborn. Aside from the irritation as a result of silver nitrate, failures in protection have often been reported. Numerous substitutes have been proposed but none has seemed to offer the same advantages as silver nitrate until the introduction of the antibiotics. These substances are now being given careful trial in an attempt to find a safe and reliable prophylaxis for this disease (Allen and Barrere, 1949).

## CHANCROID

Chancroid, or soft chancre, is an acute specific, local, autoinoculable and contagious venereal disease, caused by the streptobacillus of Ducrey. The ulcers are often multiple and confer no immunity. Chancroids are peculiarly liable to mixed



infections and are apt to become phagedenic. Infection is usually acquired by sexual contact, but accidental nonvenereal inoculation does occur.

The infection develops as a small erythematous lesion within three to five days after exposure, at times later, which shortly develops into a papule. This soon breaks down, forming an ulcer with ragged undermined edges, accompanied by an abundant, purulent secretion. The ulcers are painful and bleed easily. There is usually no systemic reaction and uncomplicated cases manifest a tendency to spontaneous healing by cicatrization extending from the edges toward the center. In about 50 per cent of cases there develops adenitis of the inguinal lymph glands and buboes, which are painful and often suppurate. The inflammation and ulceration on the penis may lead to phimosis, destruction of the frenum, gangrene and phagedena.

**Diagnosis.** From the public health standpoint the differentiation between chancroid and syphilis is paramount. This may be accomplished by darkfield examinations of serum obtained from the base of the ulcer, repeated as frequently as may be necessary. Negative darkfield tests should be followed by repeated blood serum tests.

The diagnosis of chancroidal infection may be accomplished by one or more of the following methods (Greenblatt 1943): (1) recovery of the *Hemophilus ducrei* from the lesion by spread or culture; (2) intradermal reaction utilizing an antigen made from bubo pus or the cultured organism; (3) biopsy; and, finally, (4) by exclusion, after utilizing clinical and laboratory methods and repeated search for the *T. pallidum* and the Donovan body.

It is usually difficult to find the organism in spreads from the open lesion because of the contamination of superimposed infection, but the organism may be grown in a high percentage of cases from the bubo pus aspirated under sterile conditions and grown on agar slants containing defibrinated human or rabbit blood. Skin tests are performed on the forearm by injecting intradermally 0.1 ml. of an antigen prepared from specific organisms. A positive reaction is read within 48 hours and is indicated by an area of 7 mm. of induration. The reaction usually becomes positive from 8 to 25 days after the appearance of the first chancroid. It remains positive for life.

**Treatment.** Until the advent of the antibiotics, the sulfonamides were specific therapy in chancroid. Sulfathiazole was the drug of choice, being administered in divided dosage of two to four grams daily for 7 to 12 days. Penicillin is not effective in the treatment of chancroid, but both streptomycin and aureomycin have been used successfully.

**Prevention.** The key to prevention is cleanliness. The use of soap and water immediately after exposure is practically an absolute preventive. Chancroid, aside from the possibility of a mixed infection, is relatively unimportant from a public health standpoint. Wider dissemination of information, better standards and improved personal hygiene tend to the elimination of this infection. The trend goes downward from 9,400 cases in 1947 to 3,294 in 1954 reported to the state boards of health in 48 states. Cases are now seen but seldom among the better class in private practice; they are largely confined to the public clinics.

## GRANULOMA INGUINALE

Granuloma inguinale is a mildly infectious, granulomatous ulceration caused by the Donovan body. It runs a chronic course with ulceration of the skin and enlargement of the affected lymph nodes. The term is misleading since the disease is by no means confined to the groin, nor is it always contracted in venery.

The disease was first reported by McLeod from India in 1882, and in the United States by Grinden in 1913. Corbus and Harris in 1908 reported three cases of erosive and gangrenous balanitis which were sufficiently characteristic to be considered the fourth venereal disease. Formerly it was believed to be more or less restricted to tropical regions, but it is now known to be rather widely distributed and increasingly prevalent in both northern and southern sections of the United States.

The period of incubation is not well defined, but probably varies from 8 days to 12 weeks. The initial lesion appears as a papule, vesicle or nodule which in a short time ulcerates and may be mistaken for a chancre or chancroid. The lesion usually occurs on the genitals, in the groin and often on the pubic and anal regions.

The ulceration extends by invasion of the surrounding tissues or by autoinoculations. The ulcers are usually moist and have a characteristic disagreeable odor; they are painless and may persist for years without manifesting any tendency to spontaneous healing. The draining lymph glands are involved and suppurate.

Diagnosis may be made upon the classical clinical picture of the exuberant velvety red, velvety tufts of granulation tissue. This diagnosis can be confirmed by smears and biopsy, the tissue in the former being stained with hematoxylin and eosin and in the latter with Dieterle's silver technic to search for the Donovan bodies which are round, rod-like, and grouped within and without large mononuclear endothelial cells. These Donovan bodies are said to be pathognomonic of granuloma inguinale (Greenblatt 1943, 1947; Dienst and others, 1949; Clarke, 1947).

Streptomycin, aureomycin and chloromycetin have been found to be effective in the treatment of this condition.

The differential diagnosis from chancroid depends upon the presence of the Treponema bacillus and a positive intradermal reaction. The chancre of syphilis is distinguished by spirochetes on darkfield illumination, and so on.

## LYMPHOGRANULOMA VENEREUM

(*Nicolas-Durand-Favre's Disease*)

Lymphogranuloma venereum is a subacute inguinal adenitis of venereal origin due to a filtrable virus. It is distinct from and not to be confused with granuloma inguinale. Lymphogranuloma venereum has an incubation period of from 5 to 21 days. There may be a primary lesion which is usually evanescent, but the infection is characterized by involvement of the drainage lymph nodes. The adenitis of lymphogranuloma venereum is characteristic. The nodes of a chain become fused together in a large mass which may reach half the size of a fist, and then the process breaks down with multiple fistulous openings. There may be systemic symptoms of malaise, loss of appetite, loss of weight, rheumatic symptoms, eruptions on the skin and some febrile reaction. In the female the picture is somewhat



different owing to the fact that most of the lymph channels running from the groin and vulva drain into the nodes around the lower part of the rectum. The filtrable virus causing this infection has been transferred to several lower animals—monkeys, rabbits, white mice and guinea pigs. The disease is by no means rare in America (Koteen, 1945).

Diagnosis is made by means of the Frei test, by biopsy, by auto-inoculation, by the complement-fixation test, and by the so-called inverted Frei test. The most important test, although it is not specific in routine diagnosis, is the Frei test. The most reliable and best standardized antigen for this test is the infected yolk of chick embryo (Lygranum) along with control material from uninfected yolk. The Frei test is performed similarly to the intradermal test for chancroid and is read in a similar manner. The same antigen used for the skin test may be utilized for a serologic complement-fixation test. Although this test is not generally in vogue, it is said to be a very sensitive test and of much value in early diagnosis as well as of value in judging the efficacy of treatment. The inverted Frei test is the use of pus aspirated from a bubo to form an antigen for injection into a known case of lymphogranuloma venereum. If the original case was lymphogranuloma venereum, a positive reaction will be evoked. Treatment varies with the stage: the tetracyclines in the earlier phases and chloramphenicol or sulfadiazine continued for 30 or more days after the discharges subside.

### VENEREAL DISEASE CONTROL

The same principles apply to the prevention of the venereal diseases as to the prevention of other communicable diseases. The fight against venereal diseases, however, is especially complicated and difficult because of the close association with prostitution, the problems of sex and morality. Measures that have helped the decline of tuberculosis and other infections are of less import with the venereal diseases, because they do not stop the basic urge which underlies their occurrence. There are three primitive appetites of man: hunger, thirst and the sexual appetite (libido). The first two persist throughout life; the last blooms at puberty, grows stronger during adolescence and wanes with age. Any program for the control of the venereal diseases must take into account the fact that we are dealing with a primal, impulsive and natural passion which is the greatest force for social good, when used in accordance with the laws of nature, but may result in dire consequences when these laws are transgressed. The venereal diseases are among the most widespread and universal of all human ills, and enter more largely into the marring of domestic happiness than any other disease known to man. The difficulties of the situation should not deter the health officer and all others who labor for social betterment. Successful control depends upon sympathetic support of practicing physicians, and persistent prating by health authorities, as well as a better understanding of the problem by the general public.

The general attitude toward the venereal diseases is often inconsistent. There is a natural aversion toward these afflictions, yet the principles for the control of syphilis and gonorrhea differ in no wise from those used in the control of communicable diseases in general although their application is somewhat special and more difficult. Control is bound to be ineffective as long as venereal diseases are regarded

punishment for sin. The immediate problem is the prevention of further spread of the infection. A person afflicted with a venereal disease should be treated in the same humane spirit that actuates in other diseases. The victim and/or culprit need not only sympathy, but even sympathy. Furthermore, the interests of the community require that the patient be accorded effective care and treatment. The usual attitude may well startle us when we consider that some hospitals even now refuse to take a case of syphilis or gonorrhea during the acute stages, when these diseases are especially communicable.

The attitude toward the venereal diseases is well illustrated by the changing views concerning syphilis. It was first regarded as a supernatural visitation, like other plagues. Then the disease was belittled and its seriousness not recognized nor realized—the smart set even regarded it as a distinction. Afterward it came to be regarded as something shameful. This attitude persisted for three centuries and still prevails. It encouraged concealment, promoted spread and retarded progress. Recently, it has been classed with communicable infections and regarded objectively. Nevertheless, a program for the control of the venereal diseases can be effective only if the peculiarities of this problem are taken into account.

**Laws and Regulations.** The laws and regulations which have been enacted to facilitate the control of venereal diseases are further proof of the peculiarity of these communicable diseases as compared with others in the public health program. In addition to premarital and prenatal examination laws, there is a great variety of complicated legal provisions concerning the reporting, management and control of these diseases. Some of the states require that morbidity reports be sent directly to the state department of health; others specify reports shall be forwarded to the local health officer of a jurisdiction of a particular size. Some states require the name of the patient to be reported, others have this requirement only if treatment is prematurely discontinued. A few states allow a "key" number or the initials to be used in lieu of the name. Some regulations require the name and address of the "source" of the patient's infection. It is illegal in certain states to infect another person. In others the citizen is called upon to report to the health authority the name of anyone who may be spreading a venereal disease. Druggists in some states are required to report all prescriptions relating to the treatment of venereal disease. According to some laws, the infected may not move from one place to another, may not travel from one state to another without the permission of the health officer. In several states it is illegal for a teacher to be employed who has or ever has had a venereal disease. In some, parents are held responsible for the treatment and control of minors.

It cannot be denied that the principles behind most of these laws are important factors in the control of venereal diseases, nor that some of these laws are important aids in control. Nevertheless, the venereal diseases cannot be controlled by legislation. Control of gonorrhea, syphilis and the other venereal diseases is a problem of diagnosis and treatment and of discovering how to persuade people to suspect infection. Much more will be gained by the venereal disease control officer without a badge and without a club, without authority and powers, except in a few instances. The most effective laws are those which serve actually to protect the population and which permit local departments of health to give suitable service to the physician, the clinic, and the institutions which diagnose and treat these diseases.



**Notification.** It is not possible to control any communicable disease, especially one that is pandemic, such as syphilis or gonorrhea, without a knowledge of the cases and deaths. It is perhaps even more important to collect morbidity statistics of syphilis than it is of smallpox. Compulsory methods are only partly successful against syphilis than it is of smallpox. Compulsory methods are only partly successful against syphilis than it is of smallpox. A little may be expected from voluntary registration. The public health registration of ophthalmia neonatorum is successful because this form of gonorrhea is so apparent and the consequences are so immediate and serious.

For the year ended June 30, 1949, 296,500 cases of syphilis, 342,900 cases of gonorrhea, and 7,400 cases of chancroid were reported to state and territorial boards of health in the United States (U. S. Public Health Service, 1949).

Table 4-2. Cases of venereal diseases reported to state and territorial boards of health, July 1 to June 30, 1946-1954.\* Figures indicate thousands of cases

Syphilis					
Year	Primary and Secondary	Early Latent	Late and Late Latent	Congenital	Not Stated
1946	96.2	110.7	129.1	14.2	20.8
1947	107.8	111.5	124.6	14.1	24.5
1948	81.4	101.4	125.9	14.5	22.7
1949	54.9	88.0	123.8	15.7	14.1
1950	32.8	68.4	115.4	15.1	6.9
1951	18.7	55.7	110.9	14.6	8.2
1952	12.4	40.6	105.4	10.4	7.7
1953	9.8	33.8	104.0	9.0	6.2
1954 <sup>1</sup>	7.9	25.8	96.0	7.6	4.5

Other Venereal Diseases				
Year	Gonorrhea	Chancroid <sup>2</sup>	Granuloma Inguinale	Lympho-granuloma Venereum
1946	368.0	7.1	2.2	2.6
1947	400.6	9.0	2.4	2.7
1948	363.0	8.6	2.3	2.5
1949	331.7	7.2	2.7	2.1
1950	304.0	5.7	2.0	1.6
1951	270.5	4.7	1.6	1.3
1952	245.6	3.8	1.1	1.2
1953	243.8	3.5	0.8	1.1
1954 <sup>1</sup>	239.7	3.3	0.6	0.9

\* VD Fact Sheet, December, 1954, page 10.  
<sup>1</sup> Estimated.  
<sup>2</sup> Includes some unspecified "Other Venereal Diseases."

The details of notification and reporting systems, and the collection and analysis of statistical data may be found in standard reference papers, pamphlets and books (Nelson and Crain, 1938; Nelson, 1942; American Public Health Association, 1955).

**Fundamental Factors in Control.** At any time the status of disease control in a community will depend upon the relationship between the causative agent of disease, the human host, and the environment. An appreciation of the relations

of these factors is essential for an understanding of incidence and prevalence, for effective case finding, and other intelligently directed venereal disease control efforts (Clark, 1948).

**THE AGENTS.** The biologic requirements of the various agents explain why the venereal diseases are diseases of intimate contact. These organisms require moisture to live, have low resistance outside the human host, and usually die when dry. Thus they can live only in those areas which are constantly moist.

**THE HOST.** The habits and customs of the population determine whether or not the biologic requirements of these organisms are going to be met in a manner which facilitates the spread and perpetuation of the diseases.

**THE ENVIRONMENT.** As a basic factor in the occurrence and distribution of disease, this term is used in its broadest sense which includes physical environment, social and economic environment and biologic environment. Physical environment—that is, weather, climate, etc.—has considerable effect on the amount of clothing, the proximity of contact, and the amount of moisture exchanged from person to person. The social and economic environment—including income, housing, education, medical care and availability, cost and use of medical services and provision of control measures—determine to a considerable extent the occurrence and distribution of the venereal diseases in a particular community.

Thus, the biologic characteristics of these agent-host relationships and the nature of the environment make it impossible to apply the usual control measures of communicable disease such as: (1) the elimination of the organisms in the physical environment, such as can be done in diseases not spread by personal contact; (2) the elimination of intimate contact; it may be possible to reduce contact, but the elimination of the type of contact which spreads venereal disease is absolutely impossible; (3) immunization; and (4) the practice of mass quarantine. Therefore, in view of these characteristics, our efforts in venereal disease control must be directed toward methods that will reduce *effective* exposure to the specific micro-organisms. There are at least four of these: (1) reduction of total exposure by decreasing promiscuity; which includes the suppression of prostitution, a function of law enforcement, and thoroughgoing sex education; (2) prophylaxis; (3) maintenance of adequate treatment and post-treatment requirements among discovered infections (case holding); (4) a reduction of periods of infectiousness by earlier recognition of undiscovered infections; this means *case finding*.

**Reduction of Total Exposures.** It is a sound policy to insist that gonorrhea and syphilis are communicable diseases dangerous to the public health, but no matter how strongly this is argued, the fact cannot be escaped that they are spread by *promiscuous* sexual intercourse. There can be no doubt that the spread of venereal disease is enhanced by multiple sexual exposures to multiple partners. The converse is also true. The fewer the exposures, the smaller the probability of spread of infections. This complex problem is a basic one in venereal disease control. Responsibility for its solution is divided among many agencies of varying interest such as health departments, sociologists, the police, educators, social hygienists, correctional agencies, and the like. Each of these agencies, working along diverse lines, has a contribution to make to the ultimate control of the venereal diseases.

Venereal disease control is seriously complicated by the difficult problem of prostitution, the prostitute being the most efficiently promiscuous part of the popu-



lation. Any measures taken for the prevention of venereal diseases which do not include some method for handling the problem of prostitution are doomed in advance to failure, since they will ignore the main square and root of these diseases. The following four ways of dealing with prostitution have been attempted: (1) *laissez-faire*, (2) suppression, (3) regulation and (4) the systematic treatment of all infected.

A policy of noninterference satisfies no one. Despite the difficulties and complexities of the situation, prostitution must be met with determined but humane action to lessen its extent and diminish its dangers. Prostitution must at least be made *difficult* and *distant*, for the extent of the patronage is in direct ratio to its accessibility. The total elimination of prostitution is beyond the dream of even the theoretical reformer. Any program must take into account the fact that many prostitutes are mental defectives and often need treatment and guidance rather than punishment. Suppression does not suppress. Virtue cannot be secured by legislation. Repressive measures drive the traffic into obscurity and reduce it materially. Vice is not flaunted in public but is driven into corners where seekers will find it, but where it will not entice the innocent and unwary. Between the flagrant evil of segregation and the imperfections of suppression, the choice is with the latter.

Regulation of prostitution by means of medical inspection and licensure has proven a failure wherever tried. Regulation implies the absence of any expectation of male self-restraint; it is society's tacit assent to laxity. Regulation fails because it makes vice easy, gives a false sense of security, and does not reach clandestine prostitution. The systematic treatment of all infected persons, especially of prostitutes, would go far toward diminishing the prevalence of venereal diseases. To accomplish this, we must have adequate and inviting facilities for treatment.

**Prophylaxis.** The object of this procedure is to diminish the *effectiveness* of exposure to the specific organisms through sexual intercourse. It is accomplished by the imposition of an effective barrier or by the use of substances which kill the organisms at the time of or following entry into the human host. There are three types of prophylaxis, the effectiveness being based upon the biologic characteristics of the organisms and certain characteristics of the host-agent relationship. They are chemotherapeutic, chemical and mechanical, each of which has been proved effective in the experimental animal. Military experience during World War II and laboratory experiments based upon it did not provide absolute evidence of the effectiveness of chemical prophylaxis. Chemotherapeutic prophylaxis, on the other hand, with the advent of the new antibiotics, shows considerable promise, recent experiments indicating a high degree of effectiveness. Experiences with oral penicillin prophylaxis have resulted in a reduction of as much as 90 per cent in the incidence of gonococcal infection under controlled use. The importance of this procedure in masking syphilis infection has not been established.

Many authorities believe that the use of the condom, that is, mechanical prophylaxis, is the surest protection against venereal infection, provided it is intact and is used properly. It should be employed at the very beginning of sex play. It does not, of course, protect against extragenital infection. It should be remembered that whatever type of prophylaxis is used, the use of soap and water should not be disregarded.

**Maintenance of Treatment and Post-Treatment Requirements Among Discovered Infections.** In any schedule of treatment requiring more than one visit for treatment or post-treatment examination, case-holding is of paramount importance. Case-holding begins with the patient's first medical contact. The informed patient cooperates; the confused or perplexed patient fails to carry out treatment and post-treatment examination schedules. On the other hand, the most completely informed patient may be expected to neglect treatment and post-treatment examination in the face of rough or discourteous handling, lack of privacy or poor technics which cause pain. Both the control of the discovered case and the discovery of related new cases depend upon the patient's understanding of the illness and its implications since it is the patient who will lead to many of the undiscovered cases. It is upon the patient that we depend for the name and location of his contacts. It is the physician's responsibility to explain the disease to each patient in understandable terms: the reason for taking treatment and for post-treatment examination; his outlook with and without treatment and his potentialities for cure.

Present information indicates that modern antibiotic therapy can accomplish in days what was previously accomplished in months or even years. This fact has greatly decreased the case-holding problem during the treatment period but it increases the importance of post-treatment observation. Penicillin has been found to be effective in every stage of syphilis in which its effects can be measured. Therefore, in spite of the fact that it will be years before the ultimate effectiveness of this agent is completely established, patients treated by the present methods have nothing to fear provided they remain under observation for the advised post-treatment period. At the present time (Oct. 1955) antibiotics are effective in the treatment of each of the venereal diseases. Which antibiotic will prove ultimately to be superior awaits further experience and more extensive trials of the newer forms. The evidence today is that penicillin is not excelled by any drug in its efficacy in practically all the manifestations of syphilis.

**Reduction of Periods of Infectiousness by Early Recognition.** The great volume of undiscovered infections is largely responsible for the perpetuation of these diseases. Case-finding procedures planned with intelligent case-holding objectives in view are the basic fundamentals of venereal disease control. Case-finding should not be an objective in itself. It should lead to a better understanding of incidence and prevalence, to protection of the public health and promotion of the public safety, and to adequate treatment of the infected. The case-finding methods now in use are four: (1) a high index of suspicion and judicious use of diagnostic measures in physicians' offices, hospitals and health departments; (2) screening processes, the process whereby physical and/or laboratory examinations for the presence of venereal disease are given an individual because he is a member of a group, all or most of whom are to be examined because they belong to that group (premarital, prenatal, employment, etc.); (3) public information—planned use of mass information media such as newspapers, radio, posters, pamphlets, to disseminate facts regarding the nature of the diseases (transmission, symptoms, consequences, availability of diagnosis and treatment)—in order to induce individuals to seek examinations of their own accord; (4) contact investigation.

**HIGH INDEX OF SUSPICION.** The importance of the high index of suspicion in case-finding is shown by the fact that during the last three months of 1954 physi-



cians reported approximately one sixth of the cases of gonorrhea, 48 per cent of the cases of primary and secondary syphilis, 46 per cent of early latent, 43 per cent of late and late latent syphilis and 39 per cent of congenital syphilis. Reports from physicians and hospitals in various parts of the country before 1945 showed venereal disease rates ranging from 2.7 per cent to 48 per cent of the patients who come to the offices and hospitals (Clark, 1945). Recent data on such rates are not available.

**SCREEN EXAMINATIONS.** Results of the examinations of the population based on social, economic or occupational groupings depend upon the individual group under study. These range from 0.2 per cent among white female college students to 4 per cent among Negro male college students; from 2.5 per cent among Negro high school students to 5.8 per cent among department store employees (Clark, 1945). Thus, there is a great variety of outcomes of such examinations, depending upon the individual groups under observation.

**PUBLIC INFORMATION.** Intelligent public understanding of the nature and characteristics of the venereal diseases and the objectives of the control program is absolutely essential to gain public support of the program and to ensure effective use of the diagnostic and treatment facilities provided in the community. Effective public education both accelerates case-finding and improves case-holding. It should also serve in some measure to reduce exposure and to encourage prophylaxis against infection. Measurements of the results of the public information program in the venereal diseases is expressed usually in terms of number of diagnostic observations, the number of new cases found, the number of old cases returned to observation to treatment, and the number of cases of early syphilis brought under observation. Great care should be exercised to give the public facts without overdramatization and exaggeration. It is likely that some of the undesirable legal statutes in some states today are the result of overexaggeration which led to hasty and ill-advised public response.

**CONTACT INVESTIGATION.** The choice of a case finding method will depend upon prevailing infection rates in the community and available facilities (Clark, 1945). Contact investigation is the most direct epidemiologic approach and offers the best opportunity for discovering early infectious cases. Contact investigation starts with the infected patient and proceeds cautiously into the home or the community where that person may have acquired the disease and where he might have transmitted the disease to others. It seeks to discover infection among all of his intimate contacts as early as possible and to discover infection previously overlooked or dismissed as trivial. The ultimate value of contact investigation is in direct proportion to the length of time by which the infectious period is shortened in those contacts who have syphilis. Thus, accomplishment is not measured by the number of contacts examined and treated but by the degree of success in materially shortening the contact's period of infectiousness.

The process of contact investigation begins when the patient comes into the office or clinic. This patient, or the potential patient, has vital information that is needed for success in venereal disease control. Whether or not this patient divulges this information depends upon his attitude. His attitude in turn depends upon how he is treated by clerks, nurses, investigators and the doctor.

The literature abounds with reports of contact investigation in public and private clinics on local, state and national levels. In spite of some differences in detail,

agree that: (1) persuasion is superior to compulsion; (2) success depends upon the interview with the patient; and (3) a successful interview depends upon the patient's understanding of the situation as it is concerned with him and his.

In the approach to the patient or to the contact named by a patient, one of the most important things to be remembered is the desirability of not differentiating between source and spread contacts. The expression "source of infection" carries the implication of accusation and should be avoided purposely both in the approach to the patient and to his contact. Fixing the blame is unimportant since each infection is a potential source of another one. The patient, when asked "Where do you think you got this?" or "Who gave you this?" thinks in terms of his most recent exposure or the consort he dislikes or suspects or about whom he has heard rumors. He thinks in terms of a single individual or a single exposure since (presumably) he has been informed prior to this questioning that the disease is spread from one person to another person through intimate contact. He is asked to make a decision which, because of the variation in incubation period, is difficult or even impossible for the trained physician. This question also allows the patient to maintain the concept of being wronged or of having wronged someone else. The question, "Where did you get it?", indicates only one person and ignores those exposed to the patient's own infection. It does not answer the basic epidemiologic question, "Who has been exposed to syphilis?", nor does it allow maximum epidemiologic attack. If further transmission of the disease is to be arrested, information must be sought concerning all sexual contact over intervals selected to include both the stage of active communicability and incubation period of the disease. These intervals have been variously defined but, in general, examination should be made of all contacts of the three-month period prior to the appearance of a chancre or the four to six months prior to the onset of secondary manifestations. The examination of contacts (other than marital and family contacts) of patients with syphilis of more than 12-month duration contributes little to the control of the disease. Time magnifies the difficulty in finding them and, when found, their period of communicability has already been interrupted by the natural course of the disease.

The married patient presents the first vital problem, that of the interpretation of the diagnosis to the spouse. The emotional reaction on the part of the patient may be one of self-condemnation or spouse-accusation. In either event the patient must be convinced of the necessity for examination of the marital partner. Although it is more desirable for the patient to assume the responsibility of telling the marital partner, valuable assistance can be rendered the patient by a discussion of methods of communicating the information. The decision of what to do under this circumstance will depend upon the degree of mutual understanding that exists between the patient and the spouse and the available facilities of the clinic or office to carry out the most advantageous approach.

In contact investigation, attention is focused primarily upon the patient. The patient is the key to success. Direct questioning as to sexual intimates should follow careful explanation of the disease and adequate consideration of the patient's immediate problem such as telling the family or interpretation to the marital partner. Names of extramarital contacts are readily obtained when properly sought. The "named" contact can be persuaded to submit to examination if the situation is adequately explained.



**Venereal Disease Control in 1955.** In spite of the advent of "miracle-working" antibiotics and in spite of the considerable progress that has been made in venereal disease control over the past 15 years, these diseases, particularly syphilis and gonorrhea, are still public health problems of the first magnitude. The present wave of optimism which pervades medical and public health circles does not seem to be entirely warranted at this time (Clark, 1950) (V. D. Control Today, 1955).

In 1932, Dr. Thomas Parran stated "Syphilis can never be controlled while more than one half of the cases are not recognized for more than a year after onset. There has been indeed an encouraging decline in the number of cases of primary and secondary syphilis reported by states and territories from 1946 to 1955 and less marked declines in latent, late and congenital syphilis. In late 1954 slight rise of syphilis or gonorrhea were noted in 43 states. The diagnosis of early latent, late and late latent syphilis means the diagnosis of cases which were not recognized during the first year or, indeed, the first several years of infection. These represent our failures in case-finding at a most critical time in the course of the disease. The number of cases of early latent syphilis reported each year exceeds those of primary and secondary syphilis. Furthermore, approximately 100,000 late and late latent and 8,000 cases of congenital syphilis are reported each year. These must be added to our failures. It is an old epidemiologic principle that successful control of communicable disease depends upon the recognition and the elimination of sources of infection. We are still missing, every year, more than we recognize. Thus, we must maintain or double our efforts rather than decrease them if we are to expect the control of these diseases in the future.

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# 5

## CONTAGIOUS DISEASES UNCLASSIFIED AS TO PRINCIPAL MODE OF SPREAD

### ACUTE POLIOMYELITIS

(*Infantile Paralysis*)

HOWARD A. HOWE, M.D.

Infantile paralysis is an acute infectious disease due to a specific virus. The common name is unfortunate in as much as the disease is by no means limited to infants nor is paralysis a necessary characteristic. The virus may invade the central nervous system where it affects principally the lower motor neurones in the anterior horns of the gray matter of the spinal cord, hence the name anterior poliomyelitis. Far more commonly, however, the virus sets up a benign infection in the alimentary tract, unaccompanied by signs of central nervous system involvement. The constitutional symptoms produced by the virus are protean and of variable intensity. The identifying manifestation of central nervous system invasion is weakness or flaccid paralysis of muscles or muscle groups, developing irregularly and reaching a maximum in the course of a few hours or days. If this paralysis is not incompatible with continuation of life, there ensues a period of recovery proceeding to a maximum restoration of function in the course of months or up to a year or more. In a varying proportion of patients there remains some degree of permanent crippling.

**History.** Epidemic poliomyelitis appears to be a phenomenon of the twentieth century in virtually all countries of the North and South Temperate Zones. The paralytic disease, however, was recognized much earlier, and the German physician Heine is usually credited with having differentiated it in 1840 from other diseases of the central nervous system. However, at almost the same time (1843), Collier described a malady which he called "teething paralysis" in a small group of children under two years of age in Louisiana.

During the next 40 years there were numerous accounts of paralytic cases, and the concept of infectiousness gradually emerged, but the first evidence of epidemicity came from Sweden in 1881 and 1887, where small outbreaks were described by Bergenholz and Medin. The name of Medin has since become linked with that of Heine in the annals of this disease. Caverly followed in 1894 with description of an outbreak in Vermont comprising 132 cases, the largest then recorded. From that time epidemics involving larger numbers of people have been reported with increasing frequency. It is doubtful whether this circumstance can be accounted for solely by increased recognition of the disease, although this has certainly resulted from the rapidly expanding consciousness of infectious diseases.

No account of the history of poliomyelitis can be completed without reference to Wickman (1913), whose epidemiological studies of the Swedish epidemic of 1905 laid the groundwork for modern thinking on this subject. Wickman was fortunate in being able to observe the spread of poliomyelitis through several small, relatively isolated rural communities. Although totally ignorant of the causative

gent, he was able to establish chains of transmission not only through contact with frank paralytic cases, but also to postulate the existence of numerous subclinical or symptomatic infections. Modern technics have corroborated and strengthened Vickman's conclusion, as have the epidemiological studies of Frost (1941) during 1910-1912, of Lavinder, Freeman and Frost (1918) on the historic epidemic of 1916 in New York City, as well as those of Aycock, and many other investigators.

**Etiology.** Following the successful reproduction of the disease in monkeys, and the identification of the infectious agent as a virus by Landsteiner and Popper in 1909, it was possible for Kling and his associates to demonstrate its presence in the stools and nasopharyngeal secretions of persons sick with the disease and some of those in contact with them. This work was confirmed and extended by Flexner and his co-workers. The experimental disease in the rhesus monkey was fully described, and this provided a means of identifying the virus of poliomyelitis and differentiating it from other viruses. Monkeys paralyzed following inoculation were found to be solidly immune to a second paralytic attack induced by the same virus material, but it was not entirely clear at that time whether the presence of neutralizing antibody in the blood serum of the convalescent was responsible for this. In 1939, Armstrong was successful in adapting the Lansing strain of poliomyelitis to cotton rats and mice. This provided a valuable new tool for experimental research. It led to the development of a technic by which the serum neutralization test carried out in mice could be used quantitatively for determining quite precisely the distribution and level of antibody against this type of poliomyelitis virus in experimental animals and in human populations. It thus made possible the basic work on the immune mechanisms of poliomyelitis which were of great importance in showing the way toward control by vaccination. At the same time it provided the tools for the first large scale serum antibody surveys in human populations. Of crucial importance was the discovery by Enders and others (1949) that poliomyelitis virus could be grown in cultures derived from various human embryonic organs and from monkey kidney and testis. This provided a medium more economical and efficient than animal inoculation for the isolation of virus and the measurement of antibody. More importantly, it could be adapted to the large scale production of poliomyelitis virus in high titer and relatively free from extraneous material, hence eminently suited for use as a vaccine.

With the observation that the chimpanzee is highly susceptible to alimentary and central nervous system infection after oral ingestion of the virus of poliomyelitis, Howe and Bodian (1941) provided another experimental animal which is closest to man in its clinical reaction to this disease.

Evidence for the existence of distinct antigenic types among poliomyelitis viruses was first shown experimentally by Burnet and McNamara in 1931. These observations were confirmed and extended with improved technical methods and it has recently been shown that there are at least three distinct antigenic types, which are widely distributed (Bodian and others, 1949; Kessel and Pait, 1950; Committee on Typing of the N.F.I.P., 1951). Animals immunized with one virus type are immune to a challenge inoculation with the homologous type but are still susceptible to infection with the other two (heterologous types).

**Portal of Entry.** In human infections with poliomyelitis, the virus is localized in the walls of the nasopharynx, the intestinal tract and certain portions of the central nervous system (Sabin and Ward, 1941). Since the virus has on numerous occasions been demonstrated in the alimentary tract some days before there was evidence of nervous involvement, and is frequently found in this site without any evidence of central nervous system invasion, it seems clear that the site of initial virus growth is in the alimentary tract. Virus has not been demonstrated in the olfactory mucosa or the olfactory bulbs of fatal human cases. This points strongly



to the mouth as the portal of entry, although it does not entirely rule out the nasopharyngeal passages as an accessory portal to the tissues of initial localization in the alimentary tract.

**Incubation Period.** Casey (1942a) collected a series of 37 cases which were presumed to have followed a single known exposure. The incubation period varied from 5 to 35 days, with the average at 12.2 days. This is in conformity with the incubation periods observed in chimpanzees following oral inoculation of virus; these ranged from 7 to 31 days, with an average of 15 days. Four days is the shortest incubation period ordinarily observed in monkeys following direct intracerebral inoculation. This would indicate that supposed incubation periods in man of less than four days should probably be regarded as erroneous.

**Pathogenesis.** There has been accumulated a great body of experimental evidence showing that the virus may spread along the axones of peripheral nerves and, having reached the central nervous system, continues to progress along nerve fiber pathways (Howe and Bodian, 1942). However, the relatively recent finding, both in chimpanzees and human beings, of a transient viremia during the preparalytic phase of the disease points to the blood stream as an important potential route to the CNS from the alimentary tract (Bodian, 1952a; Bodian and Paffenbarger, 1952; Horstmann, 1952; Horstmann and others, 1954). The isolation of virus from tonsils, Peyer's patches, cervical and mesenteric lymph nodes of chimpanzees before the onset of viremia (Bodian, 1955) recalls earlier descriptions of a lymphatic phase in man.

The virus attacks and either damages or destroys certain types of nerve cells preferentially. Those most seriously affected are the anterior horn cells of the spinal cord, but in severe disease the cells of the intermediate gray (this includes the spinal centers of the sympathetic nervous system) and even the posterior horn and dorsal root ganglia may be attacked. In the brain stem the scattered cells of the reticular formation, the vestibulo-cerebellar complex, the thalamus and the motor cortex are also vulnerable. Conspicuously spared is the balance of the cortex. There is no acceptable evidence that virus invades or proliferates in muscle, although it grows readily in tissue cultures of human embryonic muscle.

**Clinical Manifestation.** It is generally recognized that many poliomyelitic infections produce no symptoms at all, or that they may be associated with a nonspecific syndrome consisting of fever, malaise, drowsiness, headache, nausea, vomiting, constipation, or sore throat in various combinations. These cannot with assurance be recognized as poliomyelitis, even in the presence of an epidemic setting, unless virus is isolated. Patients who present muscle pains and stiffness of the neck or back, in addition to the previously mentioned signs and symptoms, and who also show an increase in leukocytes and protein in the spinal fluid as an indication of central nervous system involvement, may be diagnosed as having nonparalytic poliomyelitis with considerable assurance, particularly if these symptoms occur in individuals associated with frank paralytic cases. However, the distinction of the nonparalytic patients from those showing weakness and flaccid paralysis of voluntary muscle is entirely one of degree, since in both types the central nervous system is invaded. Patients with fever who complain of various discomforts but who have normal spinal fluid may be regarded only in an epidemic setting as having "abortive" or presumptive poliomyelitis.

While the clinical picture of paralytic poliomyelitis involving the central nervous system is dominated by the flaccid paralysis resulting from lower motor neuron damage or destruction, ataxia and incoordination probably secondary to brain stem invasion, have also been noted. Painful spasms of unparalyzed muscles also occur. The mechanism of these latter is obscure, but may be readily rationalized on the basis of damage to the central nervous system. Every degree of destruction

motor cells may be encountered and is reflected in signs which vary from complete and irreversible paralysis to affections so slight that disease can be detected only by the presence of abnormal protein and leukocytes in the spinal fluid.

The Coxsackie viruses have been frequently demonstrated in individuals who are also harboring poliomyelitis virus, and the clinical picture of Coxsackie infection is said on occasion to resemble that of nonparalytic poliomyelitis (Curnen and others, 1949). Similarly, signs of meningeal irritation have not infrequently been associated with the presence of mumps virus (Kilham and others, 1949). These agents, which produce an "aseptic meningitis," can at times be ruled out only by appropriate laboratory procedures (virus isolation and/or complement fixation or neutralization tests).

**Immunity.** Infection with the virus, even though asymptomatic, is followed by the development of complement fixing and neutralizing antibodies in the blood serum. The former are said to decline in titer more rapidly than the latter and thus indicate relatively recent infection, but the evidence is still accumulating on this point. Neutralizing antibody may still be present for three years after infection or possibly even as long as 20 years. Furthermore, the age at which neutralizing antibody is first acquired in the population closely follows that of the paralytic disease (Turner and others, 1950).

Since poliomyelitis is primarily a children's disease and second attacks are extremely rare, it follows also that antibody is somehow connected with immunity. Yet in a given population group, antibody titers extend over a wide range. For example, in a group of 68 young adults, mostly graduate students, Bell (1948) found type II antibody present in high titer (1:100) in 22 per cent, while the majority (41 per cent) had intermediate titers (1:10 to 1:90). An appreciable number (37 per cent) showed low titers (1:2 to 1:9) or else no evidence of antibody at the level of the test, yet these individuals all belonged to an age group in which paralytic rates average no more than 5 per 100,000. This epidemiological evidence indicates that relatively low levels of antibody suffice to insure protection against paralysis, although it has been clearly shown that adult family contacts of cases not infrequently become alimentary virus carriers (Wenner and Tanner, 1948). In recent years these deductions have received ample support from the laboratory and field where it has been possible to more clearly define the quantitative aspects of the relationship between antibody and immunity. The first steps consisted of the demonstration in monkeys that immunity to direct brain inoculation regularly followed vaccination with active or formalin inactivated virus if the quantity used was great enough to induce high levels of serum antibody (Morgan and others, 1947; Morgan, 1948; 1949). Later it became apparent in cynomolgus monkeys that much less antibody protected against paralysis following introduction of virus by peripheral routes such as intramuscular inoculation or feeding (Bodian, 1952b). In the chimpanzee, it was shown that serum antibody passively introduced did not prevent alimentary infection and that relatively low levels were associated with the absence of viremia and paralysis (Bodian, 1953). Furthermore, the experiments of Hammon and others (1953) indicated that in man barely detectable circulating antibody introduced in gamma globulin could occasionally prevent paralysis.

Meanwhile, the understanding of poliomyelitis was considerably advanced by the discovery that three immunological types of virus existed (Bodian and others, 1949; Kessel and Pait, 1950) and that these were widely distributed throughout the world (Committee on Typing, 1951). In the laboratory, at least, no one of these three conferred cross immunity against the others. It also seems highly probable from the work of Bodian in 1951 that second attacks of paralytic poliomyelitis in human beings, though rare, are due to unrelated types. All of this information, accumulating like a flood, finally led to the demonstration that relatively low levels



of antibody induced in human beings with trivalent formalin inactivated vaccine do in reality protect against paralysis (Evaluation of the 1954 Poliomyelitis Vaccine Trials).

**Provoking Factors.** Explanation has long been sought for the fact that most humans acquire their immunity to poliomyelitis through subclinical infections and nonparalytic attacks. Only the occasional individual has some degree of paralysis. The hypothesis has been advanced that the difference might be the result of some provoking factor which temporarily depressed the resistance of the central nervous system to virus invasion. The idea that disturbances in nutrition might act in this manner has been widely held but has received little support in experimental work. There is also no convincing evidence of the effects of prolonged chilling within ordinary physiological limits. There are, however, four factors which have been associated quite definitely with the occurrence of paralysis, namely, (1) excessive fatigue; (2) oral operations (as tonsillectomy and adenoidectomy); (3) the injection of antigenic materials, such as diphtheria toxoid and pertussis vaccine; and (4) pregnancy.

1. **EXCESSIVE FATIGUE.** This has long been suspected as a provoking factor, but it is only in recent years that controlled observations have been made on humans under the conditions of ordinary life (Russell, 1949). It now seems reasonably clear that the severity of paralysis is not enhanced unless the subject persists in rather violent exercise beyond the time at which signs of central nervous system invasion are demonstrable. In the absence of such signs as stiff neck, stiff back, headache and muscle pains, exercise appears to have no deleterious effect.

2. **ORAL OPERATIONS.** It is known that healthy children carry the virus in their throats and that virus has been demonstrated in tonsils removed by routine operations. In recent years, convincing evidence has accumulated that tonsillectomy and adenoidectomy may serve as provoking factors for paralytic poliomyelitis, particularly the bulbar variety. In 1942, Aycock first reviewed the subject and was able to accumulate many instances from the literature showing that among cases of poliomyelitis with a history of tonsillectomy 60 days prior to onset of paralysis there was a marked concentration of bulbar and bulbo-spinal types within the first 30 days while spinal and nonparalytic cases were randomly distributed over the entire 60-day period. It has been shown (Anderson and others, 1950) that attack rates for bulbar poliomyelitis are 10 times higher among the recently tonsillectomized as compared with the same age group in the general population.

The hypothesis that exposed dental pulp might afford a portal of entry for poliomyelitis virus has received some attention but the recent study of Finn and others (1947) failed to show any significant relationship. There is also evidence that tonsillectomy predisposes to the bulbar form of poliomyelitis at any time during life (Anderson and Rondeau, 1954; Paffenbarger and Wilson, 1955).

3. **INJECTION OF ANTIGENIC MATERIAL.** In recent years evidence has been accumulating to indicate some causal relationship between injections of antigenic materials (especially diphtheria, pertussis, tetanus antigens) and the localization of paralysis in poliomyelitis. This has been reported from England, Australia and the United States (see Korns and others, 1952, for a study in New York State and references to previous observations). It is by no means clear that under ordinary circumstances the total incidence of paralytic disease is increased by such injections and the accounts describing the phenomenon vary considerably in respect to duration and to its correlation with age. In general, there is agreement that the highest incidence of paralysis is recorded within one month after injection of antigens. The phenomenon has been most consistently observed in children under three years of age. The most striking evidence for provocation is found in the frequent localization of paralysis in the spinal cord level of the extremity injected.

Since immunizations are usually given in the arm, this results in a preponderance of arm paralysis, while ordinarily leg paralysis predominates. Primary immunizations with D.P.T. are ordinarily restricted to infants under six months of age, a group in which poliomyelitis incidence is negligible, so that this finding has had little effect on immunization programs other than to indicate the wisdom of deferring selective booster inoculations of older children to periods when poliomyelitis incidence is relatively low.

4. **PREGNANCY.** It has long been suspected that pregnancy predisposes to paralytic poliomyelitis, but this relationship has been more clearly established in recent years by careful epidemiological studies (Anderson and others, 1952; Paffenbarger and Wilson, 1955). For example, the second authors cited above compared the risk of acquiring paralytic poliomyelitis among immediate contacts of cases. They found that in a group of 89 pregnant contacts, 7 per cent developed the disease as compared with 1 per cent of 651 nonpregnant female contacts of comparable ages. Furthermore, the age-adjusted rate for pregnant females (denominator estimated) was double that for nonpregnant females or married males.

**Geographic and Seasonal Distribution.** The records of the World Health Organization and those of the League of Nations before it, indicate that poliomyelitis is world wide in its distribution. At the same time there are many countries in which the disease is known to exist but where it seldom reaches epidemic proportions. These countries almost invariably have a warm or mild climate and populations that live under primitive conditions. They also have insufficient public health organizations and medical care. Frequently the pressing problems of malnutrition, malaria, cholera, dysentery, tuberculosis, parasitic infections and the like obscure the recognition and reporting of cases of poliomyelitis. Despite this, in recent years there have been reports of small outbreaks in such countries as El Salvador, Puerto Rico, Venezuela, Ecuador, Palestine and India. These outbreaks are almost exclusively confined to children under five years of age.

While poliomyelitis is clearly not a new disease in the countries just cited, there is no doubt that awareness of it has increased all over the world. It is by no means certain whether these recent records of epidemics reflect increased recognition and accuracy of reporting, or whether they describe the transition of poliomyelitis from an endemic to an epidemic disease. There is little doubt that the latter phenomenon occurred around the turn of the past century in the countries of the temperate zone.

Reports of poliomyelitis in the Arctic have not been numerous, but it is clear from available information that the disease reaches its greatest epidemicity in these regions. In contrast with the tropics, or even the temperate zones, the virus is absent for considerable periods of years and upon reintroduction may build up high paralytic rates in young and old alike (Peart, 1949).

The propagation and/or transmission of poliomyelitis virus is apparently facilitated during warm weather, although it may take place in subzero temperatures of the Arctic. In the tropics, where small outbreaks may occur during any month of the year, they are probably only the peak variations of a high endemic level. While occasional winter epidemics have taken place in the temperate zone, midsummer and fall are unquestionably the months of highest incidence in these areas. Nevertheless, cases continue to occur throughout the colder months of the year. During years of unusual prevalence, reporting shows a definite upswing of cases as early as spring. This is shown in Table 5-1, retained from the previous editions of this book but still pertinent.

Seasonal variation is somewhat magnified by reporting deficits which were clearly demonstrated by Nelson and Aycock (1944) in a retrospective study of paralytic patients who were known to the Harvard Infantile Paralysis Commission. On searching the records in the communities where the cases had originated, these investiga-



tors found a deficit of 68 per cent in the reporting of paralytic cases which occurred between the months of January and May.

**Prevalence Rates.** Average annual rates based upon reported cases and registered deaths from poliomyelitis are much lower than those recorded for such communicable diseases as measles, scarlet fever and diphtheria, but are similar to those of meningococcus meningitis. The average annual morbidity rates tabulated by Gilliam and others (1949) for the counties of the United States from 1932 to 1946, show 77 per cent of them under 9 per 100,000 while mortality rates averaged between 0.6 and 0.7 per 100,000 in the states of the U. S. Registration Area between 1932 and 1940 (Gilliam, 1948). As might be expected with increased recognition and reporting of this disease in recent years these rates are now somewhat higher.

**Age Selection.** Poliomyelitis is a children's disease the world over, although there are some important minor differences in age selection which throw considerable light on its character. Infants are susceptible at birth and cases do occur during the early months of life, but are rare until after the sixth month, which presumably marks the waning of maternally transferred immunity. Rates range from 25 to 100 per 100,000 for children under 10 years, from 10 to 25 per 100,000 for the next decade of life and are 5 to 10 per 100,000 for those 20 to 30 years of age. At ages above 30 years they are very low. These are, of course, average rates and do not accurately describe any particular epidemic situation, although they clearly show the highest incidence of the disease to be in the youngest age groups. While the predilection of the disease for children has several interpretations, only one seems in conformity with the facts. It is not logical to assume that exposure to the virus is significantly greater in the younger age groups, since all ages live in the same homes. Neither can it be shown that mere physiologic maturity brings a type of nonspecific resistance, for the average age of paralytic patients has been considerably higher in rural areas than in large cities of the same climatic zones. The exclusion of these possibilities leaves the acquisition of specific immunity as the most acceptable explanation of the age selection in poliomyelitis. This is corroborated by the fact that the acquisition of serum antibody against the Lansing type of poliomyelitis virus closely follows the age pattern of the paralytic disease (Turner and others, 1950).

**Changes in Age Selection.** Since the first recognition of poliomyelitis as an epidemic disease, rather striking changes in age selection have taken place. For example, in the United States there has been a consistent reduction in the specific rates for children under five years. This has been noted in relation to deaths since 1910 for the Registration Area of that time by Gilliam (1948), and since 1920 in relation to total reported cases as well as deaths in five northern states by Dauer (1948). At the same time there has been a consistent shift in the incidence of reported cases (a mixture of paralytic and nonparalytic) to older age groups. During the three decades from 1910 to 1940 this involved principally the ages from 5 to 19 years with little change in the rates for adults (Dauer, 1948; Howe, 1948). However, in the period between 1945 and 1951 a further shift to the adult group has been noted (Dauer, 1955) for paralytic cases in the states of Maryland and Massachusetts. Although these rates were far from the magnitude of those observed in children of five to nine years they nevertheless showed a three- to five-fold gain in comparison with the earlier rates of this group. This is to say that in the past decade there has been a shift of paralytic poliomyelitis into relatively older age groups. These changes may not be general for the entire country, but in the areas cited, as well as in a local outbreak in Rochester, Minnesota (Paffenbarger and others, 1954), a further change was noted—a reversal of the usual male preponderance to females in the age groups between 20 and 35 years.

Table 5-1. Cases of infantile paralysis reported to the Massachusetts Department of Health

	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
January	6	14	5	4	2	10	8	10	14	9	6	6	18	4	4	9	6	1	2
February	3	2	3	2	4	10	4	9	6	4	5	2	13	3	2	4	4	1	0
March	5	8	6	2	1	7	6	5	9	7	5	3	5	2	1	3	3	1	2
April	2	9	6	4	1	3	3	4	8	2	4	4	6	3	3	5	4	0	1
May	3	9	6	—	—	6	—	4	4	1	4	7	8	8	5	3	2	5	4
June	11	15	6	3	5	4	5	4	6	2	5	11	8	4	3	15	3	3	4
July	106	38	10	5	16	26	23	8	12	11	22	22	21	4	26	60	5	78	20
August	252	38	20	12	93	63	57	25	37	30	75	176	167	9	105	433	10	149	15
September	623	16	20	9	273	55	58	37	86	43	58	376	120	21	104	588	12	83	8
October	701	11	7	17	190	27	28	48	56	31	27	377	50	33	170	234	4	23	—
November	179	10	7	5	77	15	20	40	22	14	26	146	13	19	52	56	4	6	—
December	36	4	3	3	31	10	5	23	12	10	8	65	10	9	31	19	3	4	—
TOTAL	1,927	174	99	66	693	236	217	217	272	164	245	1,195	439	119	506	1,429	60	354	56





It is interesting to speculate about the significance of this trend. Dauer attributes largely to an increase in the size of families since the 1920's and 30's. During the period of falling birth rate the average size of families decreased. Since it is now clearly clear that the virus is commonly introduced into the family by young children, this circumstance afforded less opportunity for exposure to infection and consequent immunization. Thus, the young parents of the late 40's who were the children of the less fecund decades probably constituted a group inadequately immunized against exposure from their own children (see Bodian and Paffenbarger, 1954 for analysis of the ages of donor and recipient cases during a single outbreak of poliomyelitis). Differences in family size may also in part account for the observation that both cases and antibody appear at later ages in children of higher socioeconomic groups. The observation that type II antibody is more frequently found in members of large families regardless of sociological factors seems to be a case point (Walton and Melnick, 1955).

It must be admitted, however, that other alterations in the life habits of people may also be playing a role in the changing age picture. In the countries which have shown changes in age selection, the past generation has seen marked alteration not only in public and private sanitation, but also an improvement in diet, and some amelioration of housing congestion. However, while these changes have been accompanied by striking reductions in the incidence of enteric disease such as typhoid and dysentery, there has been no reduction in the incidence of clinical poliomyelitis despite the shift in its age selection.

**Frequency of Subclinical Infection.** The ratio of clinical to subclinical cases is indicated by the survey of Collins (1946) which included 20,258 individuals from birth to 24 years of age in 28 cities of the United States. In this group, 11.01 per cent had a history of antecedent paralytic poliomyelitis, including death. Since poliomyelitis incidence is negligible over 25 years of age, these figures indicate that effective immunity had been achieved by the population at the rate of approximately 10 infections to one clinically recognized case. A similar ratio has also been shown by Casey and his co-workers (1950) on the basis of clinical-epidemiologic observations.

Table 5-2. Reported cases of measles and poliomyelitis by age groups—counties of Maryland, 1916-1943 \*

Age Groups	Measles			Poliomyelitis		
	Reported	Cumulative by Age		Reported	Cumulative by Age	
		No.	%		No.	%
0-4	24,128	24,128	24.3	614	614	51.7
5-9	43,087	67,215	67.8	282	896	75.6
10-14	16,365	83,580	84.3	157	1,053	88.9
15-19	6,772	90,352	91.2	69	1,122	94.7
20-39	7,109	97,461	98.4	53	1,175	99.1
40-59	708	98,169	99.1	5	1,180	99.6
60 +	95	98,264	99.2			
Unknown	815	99,079	0.7	5	1,185	0.4
TOTAL	99,079			1,185		

\* Figures obtained through the courtesy of Dr. Riley of the Maryland State Dept. of Health.

The ratio of clinically recognizable cases to subclinical immunizing infections is also suggested by a comparison of poliomyelitis and measles, both diseases to which most individuals reaching the twenty-fifth year of life have acquired immunity. In Baltimore, between 1921 and 1944, 119,432 cases of measles were reported among the white population, while during the same period only 898 cases of para-



lytic poliomyelitis were recorded. Similarly, in the rest of the state of Maryland exclusive of Baltimore, from 1916 to 1943 the records show 99,079 cases of measles in all races (which is probably only about 60 per cent of the true number), 1,185 cases of paralytic poliomyelitis with virtually the same age distribution (Table 5-2). It is difficult to escape the inference that there were during this period at least an average of 100 poliomyelitic infections to one reported case of paralytic disease. This, however, as in the Collins' study, represents a cumulative risk and does not describe the situation for any single epidemic.

**Epidemicity.** The term "epidemic" is entirely a relative one when applied to the clinically apparent incidence of poliomyelitis. This may be seen by comparing reported cases of poliomyelitis over a period of 24 years in a large city, such as Baltimore, with two small cities of Maryland. While the disease has been reported every year in Baltimore with periodic upswings, the smaller cities of Hagerstown and Easton have had a much less spectacular, although typical, experience with poliomyelitis.

In Hagerstown and its rural districts, poliomyelitis has been reported only 11 of the years from 1925 to 1948, inclusive. During that time the largest reported outbreak consisted of 11 cases, producing a "rate" of roughly 37 per 100 persons, which is equivalent to those reported in Baltimore at epidemic times. Easton and its environs were conscious of poliomyelitis but four times during this 24-year period. In 1941, two cases were reported, producing a "rate" of 58 per 100. The average annual incidence of the disease was almost identical in the three communities for the 24-year period, thus indicating that each was having about the same experience with poliomyelitis virus as an infectious agent. On the basis of its population and the average paralytic rates for Maryland, such communities as Easton might have produced no more than two cases as an epidemic manifestation.

Many observations attest the fact that immunization becomes less thorough with increasing dispersion of people (Olin, 1951). Thus in all probability the process was less complete in the smaller towns than in the large city although the differences were not great, as is indicated by the fact that the majority of the cases were under 13 years old in all three localities.

It thus becomes apparent that aside from differences in the degree of recognition of the disease the recurring variations in the incidence of poliomyelitis are largely conditioned by the immune status of the population plus the amount of exposure. One is inclined to stress the importance of the former, although heightened risk exposure undoubtedly plays a role in some situations, for example, the increased rates observed in British and American soldiers stationed in Africa, the Middle East, and the South East Asia Theatre during World War II (Paul, 1949). There is every reason to accept the idea of widespread and perhaps continuous dissemination of virus in such countries, since serological surveys in native populations reveal a high prevalence of antibody in children under three years of age.

The unseen portion of any epidemic is by far the larger. It may be visualized on the fact that in the city of Toronto, Canada, Rhodes and his colleagues, in 1947 demonstrated poliomyelitis virus in the sewage one month *before* the first reported case of the season. Similar findings were reported by Gear in 1948 from Johannesburg, South Africa, and in an English village (Goffe and Parfitt, 1955), where virus was still recovered in sewage two months *after* the record of the last case.

Epidemics of poliomyelitis show a frequently recurring pattern of radial spread from a more or less centralized focus. It is a common observation that the center of such an area will be "burned over" and become silent while new cases are occurring on the periphery. The direction of principal progress is unpredictable, as the slowly moving wave of infection engulfs some communities and bypasses others. The disease, however, moves most surely through areas which represent concentrated

people. The rate of progression has not varied appreciably with the advent of mid transit.

**Infectious Period and Contact Transmission.** Laboratory studies have shown virus of poliomyelitis to be present in stools during the acute stages of the analytic disease in such a high percentage of cases that it seems justifiable to consider it a constant concomitant of central nervous system invasion. Within a week of the onset of symptoms the frequency with which virus can be demonstrated in stools is reduced but, nevertheless, virus has been shown to persist in some individuals for as long as 11 to 12 weeks. Child contacts under 5 years of age show very high alimentary infection rates (80 to 100 per cent) which diminish with increasing age (Brown and others, 1954; Casey and others, 1950; Bhatt and others, 1955).

Virus has also been isolated from throat swabs of a high percentage of patients in periods as long as 13 days after the onset of symptoms (Howe and others, 1945; Horstmann and others, 1954). However, it generally disappears before virus is absent from stools. It is probable that the failure to detect virus in the nasopharynx as long as in the stools reflects a real biologic difference, since it is known that antibody may be present in the pharyngeal secretions, although it has not been demonstrated in the stools (Bell, 1948). It is therefore possible that the antibody response following infection clears the pharynx of virus in a relatively short time.

Little is known about the incidence of virus in the stools or pharyngeal secretions prior to the onset of symptoms, although it has been described in the former 17 and 19 days, respectively, before onset. There have also been a few isolations of virus from the nasopharynx four to six days before clinical symptoms were observed. The observations of Bodian and Paffenbarger (1954), Horstman and others (1954), and Bhatt and others (1955) on the appearance of antibody in susceptible family contacts leave little doubt as to the high rate of communicability shown by this disease. Investigation of the virus distribution in the family associates of the patient has amply demonstrated the relative frequency of asymptomatic virus infections of the alimentary tract, while random sampling of the population at epidemic times has suggested a wide distribution of nasopharyngeal and fecal virus carriers, many of whom were not sick (Howe and Bodian, 1947; Brown and others, 1949; Casey and others, 1950; Horstmann and others, 1954).

These studies of the excretion of the virus lead to the conviction that the principal mode of spread of poliomyelitis is by some form of personal contact of susceptible individuals with infected individuals. It brings laboratory confirmation to the original conception of Wickman and is supported by many field investigations made since that time. The frequency with which a clinical case of poliomyelitis can be traced to preceding contact with a *recognized case* varies widely according to many variables, such as completeness of recognition and reporting of cases, definition of contact, definition of case, the skill and objectivity with which the inquiry was conducted, etc. It has recently been shown (Paffenbarger and others, 1954) that a history of contact with a case is about six times more frequent among those who become cases as in the population at large. This is a surprisingly high proportion in view of the fact that so many infections are subclinical. Moreover, the literature is filled with the convincing accounts of isolated episodes in which poliomyelitis has been introduced into remote areas by apparently healthy persons or those in the incipient stage of the disease.

The precise manner in which the virus is transferred from one individual to another is not yet clear. The high infection rate among familial associates and slow propagation of the disease from one household to another suggests that rather intimate conditions of personal association are usually necessary. No one who has watched children at play can doubt that many opportunities exist for direct transfer



of either pharyngeal secretions or feces, not only among the children themselves, also to their adult associates.

Two independent epidemiological studies based upon secondary cases, presumably arising from a single contact with an extrafamilial primary case (C. 1942b; Aycock and Kessel, 1943) suggest that the infectious period is as long as eight days before and 11 days after the onset of symptoms. This was confirmed in 1949 by Silverthorne and other members of the Toronto group. This interval corresponds very closely to that during which the virus is demonstrable in pharyngeal secretions of the patient. The fact that the continued elimination of virus in the stools for a longer period of time has not been connected more frequently with the appearance of late secondary cases constitutes evidence that fecal conveyance by pharyngeal secretions. Both poliomyelitis and measles spread orally and appear to be equally infectious, yet patients with poliomyelitis do not cough or coryza which is so effective as a propagating mechanism in measles. If, however, the virus were even occasionally present in the saliva, it would not be necessary to postulate any other vehicle for its transfer. On the other hand, the parent multiplication of the virus in the alimentary tract and the excretion of large quantities in the feces argues with equal force for this medium of transfer. The concept receives further support from the fact that poliomyelitis behaves seasonally very much as do other enteric infections, such as typhoid and dysentery. However, it is a striking fact that little or no correlation can be demonstrated between the occurrence of poliomyelitis and the level of community sanitation. In spite of the advance which has occurred in the United States in community sanitation and hygiene, there has been no reduction in the incidence of poliomyelitis, although typhoid and dysentery are rapidly disappearing. The possibility exists that different mechanisms of transfer are involved and may operate under certain conditions.

Whatever the mechanism may be, the concept that the principal mode of communication of poliomyelitis is some form of personal contact is no longer just a theory; it should be regarded as an established fact. This concept is adequate to explain all of the known observations on the epidemiological distributions and characteristics of the disease. No other theory so far proposed fits all of the observations equally well. This fact, however, does not preclude the possibility that accidental and indirect routes of spread may be operative under special circumstances.

**Other Possible Routes of Transmission.** Four such possibilities have received attention and have been extensively explored: (1) the existence of an extrahuman reservoir of the virus; (2) the role of flies as vectors; (3) dissemination by contaminated milk; and (4) dissemination by polluted water supplies.

(1) Much speculation and a considerable amount of work have been directed toward discovery of a natural host of the virus other than man (Francis and others, 1948). The search has ranged through many species of animals, birds, and fish, but so far it has been unproductive. Repeated attempts to demonstrate virus in blood-sucking arthropods have been negative. In view of the transient viremia, such efforts might be regarded as insufficient; nevertheless the persistence of poliomyelitis epidemics into cold weather appears to rule out such arthropods as an important vector.

(2) The hypothesis that flies are implicated in transmission is attractive because the season of highest prevalence of the disease, like that of such enteric infections as typhoid and bacillary dysentery, corresponds roughly with the time of year when flies are most numerous. Upon many occasions, investigators have recovered poliomyelitis virus from pools of flies collected in localities where cases of the disease were occurring (Meinick, 1949). For the most part, however, the infected flies were trapped in areas where they had ready access to large quantities of human excrement. Of the five species enumerated, only the housefly (*Musca domestica*)

ely enters human habitations. Quite obviously if flies do play a role in transmission it can only be an accessory one. In several villages extensively treated with DT no difference was noted in the epidemic incidence of poliomyelitis in comparison with neighboring untreated villages despite the fact that dysentery rates were sharply decreased in the former (Paffenbarger and Watt, 1953).

(3) With every outbreak of poliomyelitis which occurs in the United States the possible implication of a common milk supply receives consideration. In the literature prior to 1929 three outbreaks have been attributed to the consumption of raw milk (see page 872). In more recent times there have been a few small focalized epidemics in which contamination of milk was a possible explanation, but the evidence has been vague and entirely circumstantial. In general, with accumulating experience, proof incriminating this medium of dissemination is conspicuous by its absence.

(4) The hypothesis that poliomyelitis is disseminated by polluted water has had many adherents. In considering this matter, a distinction should be made between transmission which may take place around the household by contamination of the private well, spring or container, through improper sanitary arrangements, or the use of a common bathtub, or by community use of the large bathtub known as a swimming pool. Short range and rather direct transmission of the virus in such a manner should be classified as one of the routes of contact infection. To be distinguished from this is the possibility that the pollution of community water supplies may be responsible in some measure occasionally for indirect and widespread exposure of consumers to infection with the virus. The evidence bearing upon this latter hypothesis has been adduced along four lines: recovery of the virus from domestic sewage, attempts to recover the virus from water supplies, effect on the virus of procedures employed in water purification, the epidemiological observations associating occurrence of cases with water distribution systems.

With appreciation of the fact that the virus was commonly present in the feces of infected persons, and that the infection is far more widely distributed in the population than is indicated by the occurrence of paralytic cases alone, it was to be expected that it could be found occasionally in domestic sewage. With the development of sensitive and reliable methods of virus detection by inoculation of monkeys, an extensive series of observations has been made, the results of which were summarized by Melnick (1947), and have been extended by Gear and his associates in Johannesburg, South Africa, as well as by Rhodes and the Toronto, Canada, group. These studies have shown that the virus of poliomyelitis may be recovered with ease during an urban epidemic from raw sewage, and from sewage in the early stages of a treatment process, and less frequently in the effluent of a sewage treatment plant. The occasional finding of virus of poliomyelitis in domestic sewage, along with other pathogens such as *Salmonella*, *Shigella* and tubercle bacilli, is without significance in the transmission of the disease, unless or until it can be shown through what channels the organisms may reach the alimentary tract of human beings. So far the virus has occasionally been traced beyond the effluent of sewage treatment works. That it may occasionally survive conditions which effect natural purification of rivers and lakes and reach the intake of water systems is a theoretic possibility only.

Up to the present, attempts to demonstrate the virus in suspected drinking water supplies are questionable or negative. It is unknown whether if present in raw water at the intake of a surface supply it would be removed by the successive stages of treatment necessary to produce a potable product which is safe by bacteriological standards. However, free residual chlorine as required by good water works practice affords an effective safeguard.

Although a large number of epidemiological studies of the prevalence and dis-



tribution of poliomyelitis have been made during the past half century, up to present no convincing evidence has been presented that pollution of a community water supply was responsible for indirect or widespread exposure of consumer infection with the virus (Maxcy, 1949).

**Control.** No disease creates more apprehension and fear in a community than does poliomyelitis. Public anxiety may find expression in pressure for unjustified restrictions which interfere with community life without having any appreciable effect on the propagation of the disease. Against these pressures the medical profession and health authorities must stand firm. The measures taken must be reasonable in the light of knowledge of the manner in which the disease spreads and in expectation of their effectiveness. In some communities, the existing regulations require practices which are not only ineffective and unwarranted by present knowledge, but which also create problems for patients and families, health officers, doctors and hospitals (Control Measures in Poliomyelitis, 1953).

Efforts should be directed to correctly establish the diagnosis of fatal, paralytic or nonparalytic poliomyelitis. Lumbar punctures should be done wherever warranted, since they provide a valuable diagnostic aid. In making a report to health authorities, the attending physician should classify the case as paralytic or nonparalytic. Physicians must also be alerted to watch for new cases, but it is desirable to keep general publicity at a minimum. If, however, newspaper discussion cannot be averted it can frequently be channeled into a constructive vein; for example, a statement that an average child of 10 years or under has less than one chance in a thousand of being paralyzed—that of those paralyzed, fully 50 per cent recoveries which are complete or virtually so. Also, the knowledge that exposure is inevitable sooner or later is more often comforting than frightening.

Certain control measures can be based upon a realistic interpretation of epidemiological characteristics of poliomyelitis. While little general importance apparently attaches to common media such as food and drink (and to stretch the point a little, one might also include swimming pools), the possibility of their being implicated under special circumstances should never be ignored. Since some remote or intimate type of personal contact appears to be the most probable mode by which the virus is spread, the large number of unrecognized infections indicates that attainment of epidemics cannot be expected from the isolation of the patient and immediate contacts, even though these may represent an appreciable number of infected individuals.

A study of two English villages (Goffe and Parfitt, 1955) attests the futility of such measures to eliminate the spread of virus. In this instance, despite the fact that family contacts were quarantined for two months following recognition of cases, virus was isolated six weeks later from the feces of a school child and demonstrated for two months in sewage drawn from areas of the larger village (population 7,400) in which no "cases" were ever recognized.

During an epidemic period all fevers in children should be regarded with suspicion. Bed rest is advisable pending diagnosis but is apparently not of great importance unless signs of central nervous system invasion are apparent. Unnecessary visiting should be discouraged and schools should be closed if they represent concentrations of children drawn from a wide area. Elective nose and throat operations and possibly all parenteral inoculations should be postponed.

Patients may be cared for at home, if home facilities and medically supervised care are adequate, or may be discharged to such a home when there is no medical indication for further observation or treatment in the hospital. Patients with poliomyelitis, or assumed to have acute poliomyelitis, are admissible to a general hospital provided that appropriate isolation precautions are employed. No special isolation or "pest" facilities are necessary.

It should be recognized, however, that with a few exceptions the above regulations are illogical in that they are designed to postpone the inevitable, i.e., final infection with the virus, to a later age. There is considerable evidence that case fatality rates and percentage of total disability increase progressively with age (Howe, 1952b, pp. 303-304). Obviously, immunization provides the answer to this dilemma.

Passive immunization with gamma globulin is too transient and costly to be of general value (Hammon and others, 1953), although it may have applications to special situations where the risk of exposure can be adequately assessed. In recent years, the development of formol-inactivated trivalent poliomyelitis vaccines has proceeded at a vertiginous rate. The first trivalent vaccines made from monkey CNS tissue (Howe, 1952a) were rapidly supplanted by preparations from tissue cultures of monkey kidney which had the advantage of higher antigenic titer and relative freedom from extraneous potential allergens (Salk, 1955). These vaccines have become available commercially and their effectiveness has been demonstrated in a field trial of unprecedented extent and thoroughness (Evaluation of 1954 Field Trial of Poliomyelitis Vaccine). For example, a "blind" study was carried out in which 402,000 children were vaccinated, of whom half served as controls since they had received only a placebo of tissue culture fluid containing no poliomyelitis antigen. In these two groups the rates for laboratory-verified cases of paralytic poliomyelitis were five times higher in the controls than in the immunized (35 and 7 per 100,000, respectively). Differences of only slightly less magnitude were noted in 221,000 second grade children, for whom 321,000 first and third graders served as uninjected ("observed") controls. These differences were of sufficient magnitude to rule out sampling variation and give an unequivocal answer as to the immediate effectiveness of this type of vaccine. For a discussion of certain long-term problems in immunization see "The Biology of Poliomyelitis, 1955."

Adequate provision should be made in the health program of a community for after care of patients who have passed through the acute stage of poliomyelitis. Expert orthopedic consultation and facilities are needed to afford maximum opportunities for recovery and speedy restoration of function with such prosthetic devices and operative procedures as are required. Not only must a patient be rehabilitated physically, but equally important is the emotional, social and occupational rehabilitation.

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## COXSACKIE VIRUS INFECTIONS

By the experimental inoculation of suckling mice, Dalldorf and Sickles (1948) recovered a viral agent from the feces of two children with symptoms of poliomyelitis living in the town of Coxsackie, New York. The agent differed from poliomyelitis virus in that it was pathogenic for suckling mice and hamsters but not for rhesus monkeys. It induced striking lesions in the skeletal muscles of the experimental animals but not in the central nervous system (Dalldorf and others, 1949). Following this lead the work of many investigators soon demonstrated that viral



agents similarly capable of producing characteristic lethal illnesses in suckling mice and hamsters could be recovered from fecal specimens not only of cases of poliomyelitis but also from patients with other diseases and from healthy individuals. By comparison of their immunologic and pathogenic properties, it was found that these viruses were not a homogeneous group. Efforts to appraise their significance in human pathology required type differentiation and epidemiologic evidence to establish their causal relationship to clinical syndromes. These studies have gone forward rapidly and it now appears highly probable that agents of this type are implicated in the causation of two syndromes, clinically differentiated many years ago, namely, herpangina and epidemic pleurodynia (Bornholm disease). Possibly there are others (Huebner and others, 1952).

**Virus Properties.** The Coxsackie viruses are extremely small in particle size, ranging from about 25 to 35 m $\mu$ . They are relatively stable. Suspensions may be preserved frozen at  $-70^{\circ}\text{C}$  or  $-20^{\circ}\text{C}$  for long periods without significant loss of titer. They survive long exposure to a wide range of pH values, and temperatures as high as  $60^{\circ}\text{C}$  or above for 30 minutes are required for inactivation. They exhibit complete resistance to ether and also to such antibiotics as have been tested (penicillin, streptomycin, chloromycetin).

**Type Differentiation.** Up to the present, 15 different types of Coxsackie viruses have been differentiated by immunologic procedures. Many strains have not been classified and it seems probable that additional types will be found. Until knowledge advances to a point where systematic nomenclature can be developed, the types have been arbitrarily named by investigators who isolated them. Thus, in the laboratory the following types have been found to be antigenically distinct (Carter and others, 1952): Connecticut 5; Ohio 1; Nancy; Texas 1, 12, 13, 14, 15; Easton 10, 14; Boston 1, 2 and 3; Alaska 5; Israel 7. Evidence permitting the differentiation of types is obtained by means of cross neutralization tests in mice, cross complement-fixation tests, protection tests in mice born of immune mothers and cross protection tests in chimpanzees. The results obtained by each of these methods have been consistent.

Further classification of these types into two groups, A and B, has been proposed by Dalldorf on the basis of pathologic differences produced in suckling mice (Gifford and Dalldorf, 1951). Group A viruses, which include 8 to 11 serologically distinct types, characteristically produce extensive liquefaction necrosis of skeletal muscles and virtually no other observable pathologic findings in suckling mice and hamsters. Group B viruses, which include at least four types, produce only mild to moderate focal muscle lesions while also causing a characteristic encephalomyelitis and extensive pancreatitis as well as other visceral lesions in both suckling mice and adult mice.

**Diagnosis of Human Infection.** Coxsackie viruses have been isolated from human sources by inoculation of suckling mice with material properly treated from feces, throat swabs, pharyngeal washings and anal swabs. Evidence that the individual from whom the material originated was infected is obtained when a rise in serum antibody is demonstrated by neutralization test with the strain of Coxsackie virus which has been recovered. Complement-fixation tests performed with human serum show in many instances responses to types other than the one isolated from the patient. These heterotypic responses are often equal to or greater than the response to the homotypic virus. Accordingly, the complement-fixation test is of little value in the diagnosis of human infection. For the present, the identification of Coxsackie virus infection can be made only by a few research laboratories equipped with the required facilities and viral reagents.

**Host-Virus Relationship.** The general pattern has been outlined by the observations of Melnick and Kaplan (1953) on chimpanzees. After the virus is admin-

ed by the oral route to an animal, a viremia may be detected in a few days. In addition, virus can be recovered from the throat commencing in two or three days following the ingestion of the virus. The agent persists in the throat for about a week. Within two to four days virus is also excreted in the stool and can be found in the stools for two or three weeks or even longer. Neutralizing antibodies to the virus when orally make their appearance within two weeks and maintain the same titer for at least one to two years.

The response of the chimpanzee is such that if several weeks or months after the initial oral administration of the virus the same strain is again administered virus can be detected in the feces but only for a period of three or four days, during which time it is presumed that the virus is passively transported through the alimentary canal. Under such conditions, a true carrier state does not develop and isolation of the virus from the blood or throat is not possible. If now, however, the chimpanzee is given virus of a different type instead of the same type, the animal responds as though it has encountered virus for the first time with the development of the true carrier state and of new antibody to the heterotypic virus. A chimpanzee which has thus been exposed to two different types of Cocksackie viruses is now immune to these two types; yet, if a third and antigenically distinct virus is fed to the animal, it will again react to the agent like a new animal. Infections in the chimpanzee are otherwise asymptomatic.

Melnick and Kaplan further observed that Cocksackie viruses had no effect on the infection of chimpanzees with three different antigenic types of poliomyelitis virus. Both poliomyelitis and Cocksackie viruses set up independent infection without apparent interaction between them.

There is evidence to indicate that the reaction of the human host to Cocksackie viruses may be much the same as that of the chimpanzee insofar as inapparent infections are concerned. Serological surveys of population groups have revealed that antigenic contact with multiple types of Cocksackie virus is a common experience (Seeman and others, 1952). Recovery of a Cocksackie virus from the throat or stools, together with demonstration of a rise in neutralizing antibody in the blood stream, is not sufficient to prove a causal relationship with the illness from which the patient is suffering. Cocksackie virus may be coincidental with, and independent of, an infection with another pathogenic agent which is the real cause of the symptomatology. Failure to recognize this fact led to a great deal of confusion about the appraisal of the pathogenic potentialities of the strains of Cocksackie viruses. They have been recovered from persons suffering from a variety of clinical syndromes including paralytic and nonparalytic poliomyelitis, poliomyelitis-like syndromes, "summer gripe," aseptic meningitis, influenza-like illnesses, fevers of unknown origin, herpangina, epidemic pleurodynia (Bornholm disease). Only with the last two is the evidence of an etiological relationship convincing.

**Occurrence.** From the reports available, it is apparent that Cocksackie viruses are widely distributed. They have been identified in parts of North America, Europe, Africa, Asia and Australia. Isolations have been made from human pharyngeal secretions and feces, from domestic sewage and from flies. Whether an extrahuman reservoir exists is not known. For the present the assumption is justified that these viruses are part of the microparasitic flora of the alimentary tract of man which is propagated by passage from person to person. Frequency of exposure is determined by conditions of living, personal hygiene, and sanitation. Infections are largely inapparent. As causes of morbidity these viruses are unimportant. Their dissemination in human society can be reduced but not obviated. Freedom from any morbid annoyance which they may occasion is gained by the acquisition of immunity as a result of natural infection.



## HERPANGINA

Herpangina was first described as a distinct clinical entity by Zahorsky in 1919. This mild febrile disease of childhood, characterized by small to minute ulcer lesions of the posterior part of the mouth and throat, received little attention, however, prior to the publication of the studies in the Parkwood, Maryland, and Westmont, Virginia, communities, and in Washington, D. C., hospitals by Huebner and others (1952).

**Clinical Course.** The incubation period is brief, two to four days. Following a brief clinical description of the disease as given by Zahorsky: "The disease begins suddenly as an acute febrile movement. The temperature often rises to 104° F. Convulsions may occur. Vomiting is often present; anorexia and prostration are sometimes marked. Throat and posterior part of the mouth show minute vesicles; some of these have ruptured small punched out ulcers. They occur on the anterior pillar of the fossae, the tonsils, the pharynx and on the edge of the soft palate. The number of lesions varies from two to twenty. Dysphagia is often marked. The general and local symptoms disappear in a few days. The disease may be easily confused with ulcerative stomatitis, which sometimes begins in the throat. Prognosis is favorable and treatment is symptomatic."

Among closely associated individuals with the same infection, characteristic vesicles or ulcers may be present in some and not in others. The febrile illness lasts from one to four days, with a mean of about 2.5 days. The blood leukocyte counts are usually normal or slightly elevated (Parrott and others, 1951).

**Etiology.** In their etiological investigations, Huebner and his associates demonstrated the presence of one or more of the six Group A immunological type-Coxsackie virus in feces or throat secretions, or both, of 85 out of 99 cases clinically diagnosed as having had herpangina. Fecal specimens examined concurrently for the presence of virus were found positive in 60 per cent of neighborhood contacts, 40 per cent of familial associates and 3.5 per cent of other normal persons living in the same communities, and hospitalized patients with other diagnoses. Serologic tests performed on specimens from familial associates of invaded households demonstrated that infection occurred only in persons without preexisting type-specific neutralizing antibody, whereas persons with previous antibody with similar exposure within the household did not become infected with homotypic virus (Beer and others, 1952). It was further concluded from these observations that children become infected repeatedly when subsequently they are exposed to different strains of virus, so that as they become older they are immunized against many virus types. The frequency with which these infections cause clinically apparent illness is undetermined. Specific neutralizing antibody thus acquired persists for at least one year and probably for many years. Thus, available evidence justifies the concept that brief acute febrile episodes of this nature, including the syndrome of herpangina, may represent a common form of the disease induced in man by the number of different types in Group A of Coxsackie viruses.

**Occurrence.** Reports on the occurrence and distribution of cases of herpangina are still quite fragmentary. It appears to be a common disease of childhood with a seasonal distribution like that of poliomyelitis. Epidemic spread occurs principally in the summertime. Cases become rare in the winter months. There seems to be no doubt that the infection is propagated from person to person by some form of intimate contact, but whether virus contained in nasopharyngeal secretions or in saliva or material or both, are media of dissemination is a matter of uncertainty.

## EPIDEMIC MYALGIA OR PLEURODYNIA (BORNHOLM DISEASE)

This clinical syndrome was first described in Norway by Daare who published a paper in 1872 entitled "Epidemic of Acute Rheumatism in Drangedal Spread

contagion." Two years later, Jon Finsen stated "rheumatism of the muscles of the chest, pleurodynia, assumes here in Iceland an epidemic character. Such an epidemic is called 'taksött,' i.e., epidemic stitch in the chest. Twice I have observed such epidemics, namely, in the summer of 1856 and in the same season of 1865." In the United States, a small epidemic of a similar condition was independently described by Dabney in 1888 around Charlottesville, Virginia, where it was popularly designated "Devil's grip." Thirty-five years later, Payne and Armstrong described an outbreak in Virginia as "epidemic transient diaphragmatic spasm." Independently, in the same year, Hanger and his associates reported the occurrence of an epidemic mild fever of unknown nature and from a clinical study of 16 patients admitted to the Presbyterian Hospital in New York proposed the designation "epidemic pleurodynia." General recognition of the disease in this country and abroad dates from the classic monograph by Enjar Sylvest (1934) entitled "Epidemic Myalgia (Bornholm Disease)," which contains a complete review of the literature up to the time and presents a detailed description of its clinical and epidemiologic aspects.

**Clinical Course.** The incubation period is two to four days. The characteristic feature of the disease is sudden onset of pain in the thoracic or abdominal region. The pain may be referred to either or both sides, to the epigastrium, the lower part of the chest or lower part of the back, less frequently to the shoulder region and extremities. It is aggravated by the use of the muscles involved. When the intercostals or diaphragm are affected, the patient tries to reduce respiratory excursions as much as possible. Breathing may become shallow and very rapid. There may be a single paroxysm lasting a few hours or it may recur one or more times, progressively increasing in severity. Tenderness on pressure and pain on motion may persist for some time.

Pain is usually accompanied by fever of variable heights and duration. There may be anorexia, nausea or vomiting at the onset. Headache is a common symptom; stiffness of the neck or back is occasionally noted. Features of pleurodynia and aseptic meningitis may be present in the same individual, with an increase in the number of leukocytes in the spinal fluid. The total and differential white blood cell count are within normal limits. The illness lasts from two or three days to two or three weeks, the average being about one week. Invariably all patients recover but convalescence may be protracted. Differential diagnosis, particularly of sporadic cases, is difficult. Appendicitis, abortive poliomyelitis, common duct obstruction, pancreatitis, coronary occlusion, pneumonia and pleurisy are some of the conditions which may be simulated.

**Etiology.** Several investigators have recently reported the recovery of Group B strains of Cocksackie virus from stool specimens of patients with typical symptoms of epidemic pleurodynia. In some cases a coincident increase in neutralizing antibody for the strain recovered was demonstrated. Laboratory infections with strains belonging to Group B produced pleurodynia-like illness (Shaw and others, 1950). One such strain was instilled into the nose of a volunteer (Findlay and Howard, 1950). Forty-six hours later he developed a typical attack of epidemic pleurodynia. Complement-fixation reaction which was negative at 24 hours after onset was positive at 72 hours and persisted for a period of 9 weeks. Accordingly, present evidence supports the concept that epidemic pleurodynia is caused by one or more of the Group B Cocksackie viruses. However, for the present, confirmation of the clinical diagnosis by laboratory tests is a research procedure.

**Occurrence.** Although in reports so far available the epidemic occurrence of this disease has been stressed, it undoubtedly exhibited endemic prevalence as well. Geographic limitations are not yet apparent but enough evidence is available to indicate that it is widely distributed in North America and in western Europe. It has a seasonal distribution much like that of poliomyelitis, peak incidence being



reached in the latter part of the summer with a decline and extremely low incidence during the winter months. The age distribution varies with the locality but a representative experience is given in a monograph by Sylvest (1934) based upon 8 cases reported in Denmark in the years 1931, 1932. About 1 per cent was in infants under one year, 10 per cent in preschool children, 26 per cent in children 7 to 14 and 63 per cent in adults. The infection is apparently propagated by some form of person-to-person contact. Whether this is effected by the virus contained in saliva material or in throat secretions, or both, is uncertain.

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### INFECTIOUS HEPATITIS

#### *(Infectious Jaundice, Epidemic Jaundice)*

Beginning with the latter part of the eighteenth century, reports appeared from time to time of epidemics of a mild febrile illness characterized by jaundice, occurring in scattered localities, in towns, institutions, villages, cities, and sometimes spread more widely. This epidemic jaundice was particularly prevalent among troops during military campaigns. It is stated, for example, that there were 42 cases of jaundice in Federal troops during the Civil War, with a case fatality of 0.4 per cent. During World War I, it prevailed from Belgium to Gallipoli, affecting troops on both sides. Similarly, in World War II, it was an important cause of morbidity. The official statistics give no adequate idea of the prevalence of disease, as large numbers of men continued on duty throughout their illness. According to Gauld (1946), because of its protracted convalescence infectious hepatitis was the greatest cause of disabling illness among the United States forces in the Mediterranean (North African) Theater of Operations. During the 27-month period, January 1, 1943, to March 31, 1945, there were over 35,000 cases of disease reported among American units in the theater. In the autumn of 1943,

tain squadron of the air corps stationed in Sicily, between 35 and 40 per cent of the command were attacked over a three-month period, and this seriously interfered with the operations at that time. At the peak of the epidemic, in the winter of 1944-45, weekly attack rates as high as 13 per 1,000 were recorded by certain divisions of the Fifth Army, and this, if maintained, would be equivalent to an attack rate of 5 per cent per month. The case fatality rate was 0.18 per cent for the three-month period. Other allied troops and axis troops in the theater suffered similarly.

In 1886, Weil clinically differentiated from infectious jaundice the disease which bears his name (Weil's disease). Later, this disease was shown to be due to *leptospira* conveyed to man through contact with rats, dogs and other animals (see leptospirosis). Blumer (1923) reviewed the occurrence of infectious jaundice in the United States, distinguishing it from the leptospiral disease. He obtained records of 11 outbreaks occurring from 1812 to 1886 and 51 outbreaks occurring between 1886 and 1920. They were scattered in almost every state of the Union. During the winter of 1921-22, the disease was widely distributed over New York State. Huntington Williams (1923) analyzed some 700 cases reported from more than 100 different communities. From these and other studies it appeared that the disease might occur at any time during the year but was more prevalent during the fall and winter months. In some populations it was largely a disease of childhood and adolescence. For example, in the New York State outbreak, 7 per cent of the cases were among preschool children, 52 per cent among school children 5 to 14 years of age, and 18 per cent in young adults 15 to 24 years, the rest being in older persons.

**Clinical Course.** As a rule the onset is rather abrupt with fever, anorexia, nausea with or without vomiting, lassitude, headache, pain in the back and limbs, and abdominal discomfort, especially in the right upper quadrant. There is no striking change in the blood picture except an early tendency toward leukopenia. After four or five days, the fever subsides, bile may be detected in the urine, clay-colored stools may be passed and clinically recognizable jaundice may appear. It varies in intensity from an icteroid tint, scarcely visible except in the sclerae, to a deep yellow, almost bronze tint. Its appearance may be delayed to as late as the twentieth day. It generally persists from a week to 10 days but may disappear after a few hours or may persist for six weeks or longer. Convalescence may be prolonged and relapse is not uncommon. About 5 per cent of cases continue to have evidence of hepatitis four months after onset, rarely longer. There is great variation in the severity of the disease, depending upon the amount of damage done to the liver cells by the virus. The very mild infection without jaundice can be recognized only if searched for with the aid of a liver function test. The proportion of infections without fever and jaundice, i.e., subclinical, is unknown, but not inconsiderable. The very low fatality in most outbreaks is a striking feature.

Blumer was one of the first to point out that the afebrile cases of infectious jaundice are clinically indistinguishable from "catarrhal" jaundice, and felt that there was justification for assuming that catarrhal jaundice was merely a name for a sporadic case of infectious jaundice. Patients dying from infectious hepatitis may present the clinical picture of acute yellow atrophy. Acute yellow atrophy is not a distinct disease entity but a syndrome which may result from the destructive action of a variety of agents on the liver cells.

**Infectious Agent.** A series of experiments carried out on human volunteers during World War II, established the virus etiology (MacCallum and Bradley, 1944; Havens and others, 1945). The disease was transmitted to human volunteers by feeding them duodenal contents from a patient with the malady and by parenteral injection of serum and whole blood and by feeding fecal material obtained from



patients. While the observations were necessarily limited, they indicated that virus was present in the blood stream of the patient before the onset and during the acute stage of the jaundice. Attempts to demonstrate the virus in urine and nasal pharyngeal washings of patients were unsuccessful. The virus was demonstrated to be in the blood and feces one month after onset of the disease and a three weeks after disappearance of jaundice (Neefe and others, 1945). Whether the patients who have relapse have the virus in blood and excrete it in the feces has not yet been determined, nor has the duration of the carrier state been ascertained.

In spite of diligent search by many investigators, no experimental animal has been found susceptible to infection with this virus. Knowledge of its characteristics is accordingly limited. It appears to be markedly heat stable, being resistant to a temperature of 56° C for at least 30 minutes. Henle and others (1950b) and Drake and others (1950) were successful in transferring the agent from cases of infectious hepatitis to chick embryo tissue culture and to embryonated hen's eggs. It was passed in series and proved capable of inducing hepatitis in volunteers. It was also found (Henle and others, 1950a) that amniotic fluids of the fifth to seventh amniotic passage series after inactivation by ultraviolet light yielded a serum test antigen which appeared specific in that positive results were obtained with convalescents of natural as well as experimental infectious hepatitis. The virus which causes "infectious canine hepatitis" in dogs is not known to be related in any way to the virus which causes infectious hepatitis of man.

**Incubation Period.** Epidemiological evidence from many sources indicated that the incubation period of infectious hepatitis was usually from three weeks to one month. However, in some outbreaks (Gauld, 1946) the evidence suggested that it was shorter, in the neighborhood of 10 to 16 days. From the results of experimental inoculations of human volunteers, it appears that clinical signs may become evident as early as 9 and as late as 38 days after inoculation. The average incubation period is 23 to 24 days. This is a distinguishing characteristic.

**Mode of Spread.** There is almost unanimous agreement that infectious hepatitis is spread by some mode of person-to-person contact. An epidemic moves at a leisurely pace through a population, usually taking several months to run its course. Cases are scattered in time, place and persons. In outbreaks in civil communities (Davis and Hanlon, 1946; Lilienfeld and others, 1953) there is a marked tendency toward familial aggregation; the risk of contracting hepatitis for members of a household of a primary case is as great or greater than a similar risk in scarlet fever, diphtheria or bacillary dysentery. Approximately two thirds of the patients report association with a recognized case, either at home or at school. That person-to-person contact was the principal mode of spread in military organizations was the conclusion drawn by Gauld (1946) from his epidemiological field studies of infectious hepatitis in the Mediterranean Theater of Operations during World War II.

Concerning the exact mode of transmission there is some uncertainty. Since the virus has been demonstrated in the feces of infected individuals, and there is some apparent association of the disease with unsanitary living conditions, it seems probable that fecal dissemination is an important mode of transfer. In spite of the failure in a limited number of human experiments to demonstrate the presence of the virus in the nasopharyngeal secretions of infected persons at the beginning of their illness, the possibility of respiratory transmission must still be recognized. The seasonal distribution is suggestive of a respiratory mode of spread rather than transmission through the gastrointestinal tract; possibly both mechanisms are operative. There is no evidence to support the concept that the infection is carried by an arthropod vector, although it is possible that at times flies may play a mechanical role in contaminating food.

Occasionally, explosive outbreaks occur due to dissemination by a common

edium. Possible illustrations are the water-borne outbreak in a summer camp investigated by Neefe and Stokes (1945); the milk-borne outbreak investigated by Murphy and others (1946); and the food-borne outbreak investigated by Read and others (1946). Warren (1953) has reviewed the outbreaks which have been reported in the past 15 years and classified them according to probable mode of spread.

Finally, the virus may be transferred artificially from an infected to a susceptible individual by transfusion of blood, plasma or serum, or by the use of improperly sterilized syringes or needles (Droller, 1945). Even the minute amount carried over in the syringe or needle, used without proper sterilization between patients, may be sufficient to infect. In either event the inoculated individual if susceptible will come down with the illness after an incubation period of from 9 to 38 days, thus differentiating the virus of acute infectious hepatitis from that of serum hepatitis which will be discussed later.

**Prevalence.** On account of the mildness of the disease, the frequency of subclinical or inapparent infections, and because routine reporting to health authorities is not required, infectious hepatitis is much more widely prevalent than is appreciated. The fact that it is principally a disease of children and adolescents argues for the interpretation that most individuals have acquired immunity by infection before they reach adult life. In the larger urban communities it is probably more or less constantly prevalent on an endemic level. When the virus has been absent from a community for long periods of time and a susceptible population has accumulated, if the disease is introduced by an infected individual it may spread widely causing an epidemic. This perhaps explains why epidemics are more frequent in isolated towns and institutions.

**Control.** There is little that can be done to prevent or postpone exposure to the virus of infectious hepatitis except by general measures of personal cleanliness, home hygiene and community sanitation. Recognized clinical cases should be isolated for a week following onset, with appropriate attention to safe fecal disposal. Interference with the activities of familial contacts is not justified. When a group of cases occurs in a short period of time in a community, school, institution, or military organization the possibility of dissemination by a common vehicle, water, food or milk should be investigated. In any case inquiry should be made into the possibility of infection by transfusion of whole blood, plasma, or serum, or by contaminated needles or syringes used in parenteral injections.

Durable protection can be gained only with immunity acquired through recovery from clinical or subclinical infection. Human gamma globulin confers temporary passive protection if given during the incubation period up to within six days before the onset of the disease. The dosage necessary is about 0.02 ml. per lb. body weight (intramuscularly). The protection afforded by this procedure may last six or eight weeks, or more. It is recommended for exposed persons who because of their general condition are poor risks for any infectious disease, and it may be used effectively to check an institutional epidemic (Havens and Paul, 1945; Capps and Stokes, 1952).

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## SERUM JAUNDICE

(*Homologous Serum Jaundice, Serum Hepatitis, Hepatitis B*)

Between October, 1883, and April, 1884, a jaundice epidemic attacked personnel of the shipbuilding and machinery factory in Bremen, Germany. It was investigated by Dr. A. Lürman (1885). His report is an example of careful, painstaking observation, which led to a clear logical inference completely out of the sphere of the existing knowledge and theory of his time. The clinical course of illness was not essentially different from that which had been described in many of the previous epidemics of jaundice. In all patients it began with symptoms of gas, or gastrointestinal catarrh which lasted at least eight days, and sometimes for weeks before the appearance of jaundice. During this time, the patients complained of pressure and fullness in the region of the stomach, loss of appetite, nausea, vomiting, dizziness, disinclination to work, etc.; more frequently, constipation was present, seldom diarrhea. He mentioned as diagnostic signs clay-colored stools and presence of bile in the urine. None of the cases was fatal. The illness lasted months in one instance, but usually followed an afebrile course of only a few weeks' duration. By systematic analysis of the habits and activities of those who became ill in comparison with those who had not, he excluded the etiological factors which had been considered in previous epidemics, such as atmospheric influence, bad diet, liquor and drinking water. The only factor which he found to be common to those who had become ill was vaccination against smallpox which had been carried out on all employees between August 14 and September 1. Humanized glycerine lymph was used by the scarification technique, employing vaccination lancets; after each vaccination the instrument was washed in 1 per cent carbolic solution. Among 1,289 persons vaccinated, 191 developed jaundice at an incubation period ranging from two to eight months. Of 87 persons vaccinated by other physicians and with other lymph none became ill. Among about 500 persons

workers employed after termination of the vaccination period, none succumbed to icterus. Lürman was unable to give an explanation for the strange causal connection.

It was many years before the possibility of transmission of jaundice by parenteral inoculation of human serum was again considered. In England, during 1937, 41 of 109 recipients of a single batch of measles convalescent serum administered subcutaneously developed jaundice after an incubation period ranging from 16 to 114 days, and eight died of hepatic necrosis. This report was amplified by a memorandum prepared by the Medical Officers of the Ministry of Health (1943) entitled "Homologous Serum Jaundice." In addition, reference was made to a similar outbreak, investigated by Chesney and others in 1942, in 266 British troops who were each given less than 14 ml. of Seitz-filtered mumps convalescent plasma in one or two doses intravenously; 86 developed jaundice. It was furthermore stated that 12 cases of jaundice had been reported from several sources in persons who had previously been given transfusions of plasma or whole blood.

In the meantime, Findlay and MacCallum (1937) reviewing their experience during the previous four and one-half years in developing a satisfactory preparation of yellow fever vaccine, reported that among 2,200 persons immunized there had been 52 cases of jaundice, developing from two to seven months after the inoculation. They suspected that the source of the icterogenic agent was in the human serum used in the preparation of the vaccine but were unable to prove it conclusively. In a much larger experience in Brazil, Soper and Smith (1938) and Fox and others (1942) reported the occurrence of jaundice after a long incubation period in individuals who had received certain lots of yellow fever vaccine in which human serum was used in very small amounts to stabilize the virus. Yellow fever vaccination was made compulsory in the U. S. Army and Navy during World War II. Beginning in March, 1942, there was a sudden great increase in the number of cases of jaundice reported from various posts of the Army, in and outside the continental United States. Investigations then instituted by the Army Epidemiological Board established a causative relationship with the administration of yellow fever vaccine. Seven out of some 130 lots which had been used were implicated. Evidently the icterogenic agent had been introduced with serum in human donor pools which had been added to these lots, and the antibodies from other donors to the pool were not sufficient to neutralize it. Although the amount of human serum in each ml. of vaccine was exceedingly small, it was sufficient to infect and cause clinically recognizable disease in 10 to 15 per cent of the recipients (Sawyer and others, 1944). Administration of yellow fever vaccine containing serum was discontinued on April 15, 1942, but because of long incubation period, cases of hepatitis continued to occur throughout the year. A total of more than 51,337 cases and 62 deaths were reported in the Army (Walker, 1945). A serum-free preparation was substituted and no jaundice proved to be associated with yellow fever vaccination developed subsequently.

The discovery of the occasional presence of an icterogenic agent in human serum also offered an explanation for the observations which had been recorded for many years of the occurrence of jaundice among syphilitic patients treated with arsenical drugs or bismuth. It now became apparent that this form of hepatitis might result from transfer of the infectious agent by improperly sterilized syringes or needles. This mode of transmission was soon found to be not infrequent in clinic and hospital practice. Very little blood or serum of an infected carrier is necessary to transmit the disease. The causative virus resists the cursory type of sterilization often practiced in busy clinics in which numerous blood samples are drawn and many injections have to be given in a short time. During an ordinary venipuncture some of the blood may be sucked back from the syringe when the tourniquet is released, permitting infected material previously present in the syringe or needle to



enter the blood stream of the patient. During the course of an injection some blood or serum from the patient may be forced up through the needle during the contraction of the recipient's muscle thus resulting in contamination of the syringe, traces of blood serum left on the tip or within the needle when it is removed from the syringe may be aspirated in the barrel. Numerous reports of syringe-transmitted hepatitis have been made (Sherwood, 1950).

By way of summary of these and other studies, cases of homologous serum jaundice were traced (1) to transfusion of whole blood or plasma or serum, both fresh and preserved by freezing or drying from frozen state; (2) to the injection of convalescent measles and mumps sera; (3) to the injection of small amounts of human serum in yellow fever vaccine; and (4) to the accidental transfer of a drop or two of blood from one patient to another by an unsterilized syringe used for routine venipuncture or from "sterile" syringes often used for multiple injections of arsenicals and bismuth in syphilis clinics.

**Frequency of Transfusion Jaundice.** It follows that the frequency of jaundice is lowest in transfusions of whole blood from a single donor to a single recipient and greatest in transfusions of pooled plasma or serum. An illustrative experience in England is reported by Spurling and others (1946). They gave the results of follow up of 2,040 patients transfused with pooled serum, and or plasma, of 1,284 patients transfused with whole blood only, and 1,284 control patients not transfused who were in the hospital at the same time as those receiving whole blood. The incidence of jaundice in the patients receiving pooled plasma or serum was 7.3 per cent. No patient receiving whole blood developed frank homologous serum jaundice. There was no case of jaundice among the controls. Similarly, in New York State, Brightman and Korns (1947) followed up 649 patients who had received transfusions of dried pooled plasma and found the subsequent incidence of homologous serum jaundice to be 4.5 per cent.

**Source and Character of the Icterogenic Agent.** The icterogenic agent is present in the blood serum of an unknown but variable proportion of individuals who are apparently healthy and who present themselves as donors. There is no practical laboratory test available by which these individuals can be identified nor can they be excluded by the absence of history of previous suspicious illness. How the agent is propagated in human populations is unknown. All attempts to transmit it to experimental animals have failed. Knowledge of the characteristics of the virus has been gained from clinical observation and experiments on human volunteers. The agent is filtrable through Seitz EK filters which hold back bacteria. It is relatively heat stable, resisting 56° C for 60 minutes and is relatively resistant to the ordinary antibacterial preservative. It survives in a serum preserved by addition of merthiol 1:2,000 or of tricresol 0.2 per cent.

**Relationship of Epidemic Hepatitis to Serum Hepatitis.** Clinically serum hepatitis cannot be differentiated from infectious hepatitis. Moreover, infectious hepatitis has resulted from the injection of serum from an active case of infectious hepatitis. Whether the two icterogenic viruses are independent entities or variants of the same virus is yet to be determined (Stokes, 1953); they differ in the following respects:

(1) *Incubation period.* While the incubation period of infectious hepatitis is 9 to 38 days, average about 24 days, the incubation of serum hepatitis is much longer, 6 weeks to 6 months, average about 12 weeks.

(2) *Infectious hepatitis spreads by contact* among groups naturally exposed or by milk, food or water, while serum hepatitis rarely if ever spreads in this manner.

(3) In a limited number of human experiments, whereas infectious hepatitis has been reproduced by *feeding stools from active cases*, and sometimes by *feeding blood taken at the onset*, serum hepatitis has not been transmitted by feeding stools.

and only once by feeding icterogenic serum, although the latter may be readily transmitted by the parenteral injection of the serum.

(4) Observations on human volunteers confirm the epidemiologic experience that, while there is homologous immunity, patients who have had infectious hepatitis are susceptible to serum hepatitis and vice versa.

(5) While the administration of *gamma globulin* is apparently effective in prophylaxis of infectious hepatitis, its similar use for the prevention of serum hepatitis is disappointing. This may be due to the long period of viremia present in the long incubation period in patients with serum hepatitis.

**Prevention.** The prevention of serum hepatitis follows largely from what is known about its mode of transmission. Efforts to exclude the risk of transfer of the icterogenic agent in transfusion by examination of blood donors is not reliable. Individuals may have the virus in their circulating blood without having recognizable signs or symptoms. Nevertheless, every effort should be made to reduce the risk by careful examination of donors. Anyone should be excluded who gives a history of having had jaundice in the previous year, recent transfusions of blood or blood plasma, exposure to infectious hepatitis in the preceding few months, or who on examination is found to have fever, scleral icterus, biliuria, enlarged, tender liver.

Transfusion of whole blood from person to person is preferred to the practical use of pooled plasma. There does not exist at present a satisfactory method for inactivation of hepatitis virus in whole blood, plasma or serum. In a human experiment conducted by Drake and others (1953) gamma globulin prepared from the blood of homologous serum hepatitis convalescents did not protect volunteers against disease after injection with an unknown amount of virus as contained in blood or serum obtained during the early stage of illness from other volunteers.

In institutional, clinic and private practice, collateral causes of transmission of viral hepatitis can be removed by requiring that all instruments used to puncture the skin or to collect blood be sterilized by dry heat (160° C) for a minimum of one hour or autoclaving or boiling for about 15 minutes. More specifically, the recommendations are as follows: (1) that in the performance of venipunctures to collect blood a freshly sterilized needle or syringe be used on each patient; (2) that in skin punctures to draw blood for examination, a fresh heat-sterilized lancet be used for each patient (hollow needles should not be used for this purpose); (3) that in giving parenteral therapy and prophylactic immunizations of all types the same precautions should be taken. Injections should not be given to successive patients out of the same syringe. There is little evidence regarding the hazard of intracutaneous administration of skin-testing antigens, such as tuberculin, out of the same syringe. There is considerable advantage in ease of administration and economy of material when a 1-ml. syringe is filled and 10 successive intracutaneous injections given from it, the needle being flamed or changed between injections. The danger in this is probably too remote to outweigh its advantages. However, a tuberculin syringe should be discarded and resterilized when emptied.

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## YAWS

(*Framboesia*, *Treponematosis*)

Yaws is a specific contagious disease prevalent among primitive peoples in tropics, resembling syphilis in its course and characterized by striking cutaneous manifestations. In the earliest stage there is a primary lesion in the form of an ulcer or granuloma, usually located on exposed portions of the body, particularly on legs, and often appearing at the site of a pre-existing wound. In from six weeks to three months after the appearance of the initial lesion, the patient suffers from malaise, headache, joint pains, with or without fever, and a secondary eruption develops. Papules and granulomatous nodules appear over various parts of the body. This generalized stage lasts from three to four months to two to three years, characteristic nodules coming out in successive crops in long-standing cases. In some patients, the process goes on to a tertiary stage with destructive bone, joint and skin lesions. Unlike syphilis, it does not attack the central nervous system or viscera and is not transmitted congenitally.

**Cause.** Confirming observations made by Thompson in 1820 and Maxwell in 1839, Pautet in 1848 inoculated 14 Negroes with a secretion from framboesia granulomata. All of them developed yaws in from 12 to 20 days. Native mothers in some areas were known to inoculate their children by scratching the arm and transferring the matter from the lesion of an infected person. They believe that children were bound to have the disease at some time and that the younger the child had it the easier it would be on them.

The causative agent *Treponema pertenue* was discovered by Castellani in 1905. It has been found in the epidermis of the yaws granulomata and demonstrated in lymphatic glands and spleen and in some instances in the bone marrow. The organisms are morphologically and culturally indistinguishable from *Treponema pallidum*. Furthermore, patients with yaws develop a positive Wassermann and flocculation test. Monkeys and rabbits can be infected by inoculation with discharges from yaws lesions. Experimental infections in rabbits with *T. pertenue* showed consistent and significant differences from those produced by *T. pallidum* (Turner and Chesnut, 1934). Nevertheless, there is a close immunological relationship between the two species of treponemas.

It has been demonstrated by experimental inoculation of man as well as animals that one attack of yaws confers a high degree of protection against reinfection. In man this immunity develops slowly. Within the first three years reinoculation may give rise to a modified attack of yaws but after a period of 10 years a majority of persons infected with yaws are refractory to reinoculation. According to Turner (1936) syphilis also confers some degree of immunity to yaws.

**Mode of Transmission.** Yaws is not a venereal disease. Infection in man occurs most commonly by contamination of a skin wound with secretions from an open lesion of an individual afflicted with the disease. This transfer may be media-

rough flies. Kumm and Turner (1936) advanced evidence which suggested that in Jamaica a minute fly, *Hippelates pallipes*, may play a role. Enormous numbers of these flies were observed on ulcerative lesions. Experimentally it was found that *pertenue* remained actively motile for about seven hours in the esophageal diverticulum of the fly. In the stomach and proboscis they lost their motility quickly. Rabbits could be infected by scarifying the skin and exposing them to *Hippelates pallipes* which had fed on infected discharges. These investigators suggested that mechanical transfer might occur by regurgitation of diverticulum contents from a preceding feeding. The relative importance of flies in transmission as compared with transfer by contact, fingers and objects contaminated by wound secretions, is undetermined and naturally varies with circumstances.

**Prevalence.** The requirements for transmission limit the distribution of this disease geographically and socially. It is primarily a disease of primitive peoples. It is encountered in equatorial Africa, and recently has been particularly prevalent in Kenya, Tanganyika and Uganda. There is evidence that the original home of yaws was among natives in Africa and that it spread to different parts of the world by the slave trade. However this may be, the disease was extremely common in West Indian slaves brought to the West Indies and tropical America, where it is still prevalent in certain populations. It has a scattered distribution among the peoples living in Southeast Asia and on the island archipelago adjacent to it—in the Malay Peninsula, Assam, upper Burma, Indochina, Dutch East Indies, Ceylon, the Philippines, Fiji and Samoa.

Where it is extensively prevalent, it is very largely a disease of childhood. About two thirds of the cases occur before puberty, although no age is entirely exempt. In a study of 23,000 persons living in a yaws-infested rural area in Jamaica, B.W.I., Saunders and Muench (1937) found that the proportion of the population with yaws increased rapidly to a level of 70 to 80 per cent at 15 to 20 years of age, after which there was a gradual decrease. Annual infection rates among previously unaffected persons rose sharply to a peak of about 20 to 30 per cent at eight years of age; this was followed by a more gradual fall. They found few new infections after 30. In other words, the disease prevailed so extensively in these areas that a majority of the population acquired immunity through attack before they reached maturity.

Turner and Saunders (1935) and Saunders and others (1936) called attention to the fact that yaws has remained localized in certain sharply limited areas in Jamaica, while having every opportunity to permeate all parts of the island. This suggests that in some localities there are factors limiting its spread and in others influencing factors to favor its propagation. Just what these factors are is not yet clear, although, in general, the prevalence of the disease is associated with areas in which there is a heavy rainfall, a fertile, moisture-holding soil supporting an abundant vegetation and a primitive population living under poor, neglected and insanitary conditions.

**Control.** Complete and permanent elimination of yaws from a primitive population can be effected through a profound change in the social and economic status, habits of life, and mental attitude. Nevertheless, a considerable degree of amelioration is possible under favorable circumstances by the reduction through treatment of sources of infection in a community. The disease is even more amenable to treatment than is syphilis, and through use of the same drugs. The administrative problem resolves itself very largely into the organization of appropriate stationary or traveling clinics. With the development of the use of penicillin, a definite advance has been made. With this drug, mass treatment carried on by a few clinics will bring a large measure of relief to an infected population. It must be followed up, however, by subsequent supervision of a district and by resurveys for the purpose



of discovering relapses and new infections, which in turn must be subjected to treatment. In the course of time, with repetition of this effort, the attack rate of yaws among susceptible persons can be greatly reduced, if not eradicated.

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### LEPROSY

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Leprosy is a chronic specific infection, characterized by nodules in the skin and mucous membranes (lepomatous type) or by a macular eruption (tuberculoid type). Nerve changes, with resultant anesthesia, atrophy, and deformity, occur in both types. Secondary manifestations in the lepomatous type (mixed leprosy) but are primary and more severe in the tuberculoid. Acute exacerbations and remissions occur in both. There is a disturbance of calcium metabolism, the diffusible form usually being decreased and the colloidal increased. In lepomatous leprosy, complications, especially tuberculosis and amyloidosis, shorten life; in tuberculoid leprosy, life expectancy is unaffected.

The fear of leprosy is almost without parallel, due to biblical influence. Among many people, however, especially where the disease is prevalent, it is of no greater concern than tuberculosis is with us.

**Incubation.** It is difficult to place the period of incubation with any certainty. It is usually stated as from six to eight years, but may vary from a few months to 20 years. Leprosy develops very slowly and commonly exists several years before it is recognized.

**Prevalence, Geographic Distribution, History.** The number of cases in the world is estimated at more than three million. The story of the spread of leprosy over the globe is one long record of transmission by human travel. High endemic prevalence now is chiefly in the tropics, although every country has some cases, either imported or of domestic origin. The countries now having a high leprosy rate (above 5 per 1,000) have a hot climate with high annual rainfall. Asia and Africa number cases by the hundreds of thousands. There is some evidence that the epidemic course of leprosy runs for decades and centuries rather than weeks, months and years. The epidemiology of the disease tends to chronicity in the community as in the individual.

**IN EUROPE.** Five to six hundred years ago leprosy was prevalent throughout Europe. It is estimated that there were 19,000 lazarets, 2,000 being in France. The decline of the disease during the fourteenth and fifteenth centuries and

rise and fall in Norway during the nineteenth century are remarkable features in the history of the disease. At present it remains chiefly around the southern borders of the continent being still of public health importance only in Portugal, Spain, Italy, Rumania, Yugoslavia, Greece, and the U.S.S.R. Residual foci persist in several other countries.

**IN AMERICA.** Just when and how leprosy came to the western world is unknown. It is likely that it was brought in by slaves. It first attracted attention in the United States in the early part of the past century, when it was recognized in Louisiana. In 1902, a census showed 278 cases, the majority of these probably having contracted the disease in the United States. In 1955, the National Leprosarium at Carville, Louisiana, had about 310 patients; and counting discharged, absconded, those under private physicians and unrecognized cases, there were probably at least twice as many outside the institution. Except in the Gulf Coast states, especially Florida, Louisiana and Texas, leprosy shows little tendency to spread in the United States. A few persons have contracted the disease in California and Minnesota. Puerto Rico, the Virgin Islands (especially St. Croix) and the Panama Canal Zone have a fair number of cases.

Mexico has a high prevalence. The Central American republics have much lower rates. There are many cases of the disease in South America; the highest prevalence rates are found, in descending order, in Brazil, Venezuela, Paraguay, Colombia, Bolivia and Argentina. Brazil registers about 5,000 new cases annually.

**IN THE HAWAIIAN ISLANDS.** In the past century most of the islands of Oceania became infected. Among these, Hawaii is of special interest. The disease appeared probably about 1820 and by 1865 had become so much of a public health problem that the then Hawaiian government established a settlement on the island of Molokai, which has become famous from the fact that the Belgian priest, Father Damien, who labored among the patients, contracted leprosy. Prevalence reached its maximum about 1890 with 1,200 cases. Since 1949 new patients requiring isolation have been admitted to a new hospital, Hale Mohalu, Pearl City. On June 30, 1955, there were 325 patients at both institutions and 227 on conditional release. Only 20 cases were discovered in 1954-55. The disease from the beginning has been found predominantly among the native and part-native elements of the population, although other groups have been affected to some extent.

**Etiology.** Hansen (1874) described the bacillus of leprosy (*Mycobacterium leprae*). This was confirmed in 1879 by Neisser and subsequently by many other students of the disease. The bacilli are acid-fast and resemble morphologically the tubercle bacillus. They do not grow on artificial media and are not pathogenic for the lower animals. They are present in greatest numbers in nodules of the skin and mucous membranes, but are widely disseminated throughout the body and even occur in the blood during febrile stages which may precede the breaking out of fresh epromata (lepra reactions). The bacilli of leprosy are found crowded within actively phagocytic macrophages (lepra cells), which may become vacuolated (foamy cells), and within "globi," the nature of which is unknown. In the tubercloid form they are found in the nerves but often rarely or not at all in the cutaneous macules. They have been encountered in the spleen, liver and testicles; in fact, in all the lesions of the disease. Acid-fast bacilli resembling leprosy bacilli also appear in the feces and expectoration.

From the standpoint of prevention, the location and number of bacilli are important. They leave the body from any of the lesions which are broken down. They are discharged in enormous numbers from the degenerated nodules of the skin and mucous membranes. They occur in discharges from the mouth and nose, for lesions in the nose and throat are common. The bacilli that remain locked up in the nerves in the purely anesthetic cases present no public health hazard.



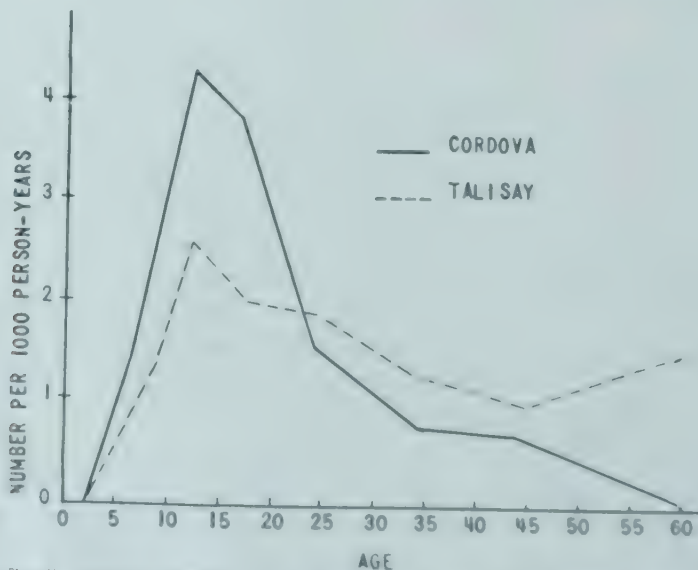
Hansen's bacillus is accepted as the cause of leprosy because it is invariably associated with the disease and often in great numbers, but Koch's laws are far from being complied with. We really know little about this bacillus. Acid-fast bacilli occasionally have been cultivated from leprotic lesions by different methods and by a number of bacteriologists, but these cultures show considerable variation and apparently represent a number of species. Except in these instances, no method of cultivation, including tissue culture and addition of various symbionts, has been successful, even when the inoculated tissues have been teeming with acid-fast bacilli. The unfortunate lack of a susceptible experimental animal is a serious handicap to the identification of the leprosy bacillus.

**Immunity.** Leprosy is a disease of man only. As far as is known, somewhat similar diseases in rodents, water buffalo, fish and birds have no relationship to human leprosy. There is no racial immunity. The long incubation period, chronic course and tendency to spontaneous healing indicate that the body must possess a high degree of resistance to this infection. Rogers believes that at least 50 per cent of persons infected do not develop clinical leprosy. The lepromin test introduced by Mitsuda in 1916, when positive, apparently is an indicator of resistance. Lepromatous patients nearly always give a negative result; tuberculoid are positive in the great majority of instances.

Highest attack rates are seen in those who have been exposed in early life. In the Philippines, the incidence is highest at 10 to 14 years of age. Above the age of 30 years the liability to contract the disease, even when exposed in the household, rapidly decreases, although no age period is entirely exempt. Fifty per cent of cases occur before 20 years of age and 66 per cent before 25 years; few cases start at 30 years. In this regard leprosy is somewhat like tuberculosis. These well-established facts bear upon prevention.

Lepromatous leprosy usually is about twice as frequent in males as in females. This may be due to relative susceptibility of the sexes, or to modes and opportunities of infection.

Many leprosy patients become tuberculous, especially in the late stage; in fact, leprosy is one of the number of infections that predispose to tuberculosis. Tuberculosis and leprosy have many points of resemblance. There is special susceptibility in childhood and early adolescence; in both diseases resistance develops with maturity. A point of difference is higher incidence of tuberculosis among females in early adult life.



From Deull, Guinto, Rodriguez and Bancroft, *Internat. J. Leprosy*, 10:107, 1942.

Fig. 5-1. Annual incidence of leprosy, Cordova and Talisay, P. I., by age groups.

There is an interesting serological relation to syphilis. In Cochrane's series (1947) the percentage of patients with a positive Wassermann varied from 41 per cent in lepromatous cases to only 4.5 per cent in neural; antiluetic treatment in a small series did not affect the reaction. Most leprologists consider that a positive Kahn or Wassermann in the great majority of instances is attributable to leprosy and not to syphilis.

**The Experimental Disease.** Leprous material has been inoculated into human beings by Danielssen, Profeta, Cagnina and Bargilli with negative results. However, most of these experimental attempts were done on adults who are resistant to this infection. In Arning's well-known case of the convict Keanu, who was pardoned on condition that he allow himself to be inoculated with leprosy, the disease did develop, but the experiment is somewhat spoiled by the fact that the man lived in a leprosy focus and had leprosy relatives. In this case a piece of leprosy material was planted into the subcutaneous tissue of the left arm. One month after the inoculation, pain appeared in the arm and shoulder and four and one-half months later a typical leprosy nodule was found. Four years later the patient had advanced leprosy.

Many unsuccessful attempts have been made to transmit leprosy to the lower animals. Lesions simulating leprosy have been reported in the guinea pig (Clegg); in the Japanese dancing mouse (Sugai); in rats (Marchoux); in the monkey (Nicolle, Duval, McKinley). It is questionable, however, whether the disease has been reproduced in the lower animals. Rat leprosy needs separate mention.

**Rat Leprosy.** There is a disease among rats which is a close counterpart of leprosy in man. It occurs naturally in *Rattus norvegicus* and may be transferred by inoculation to the more tractable laboratory white rat. The disease was first observed by Stefansky in 1903 in Odessa. In the same year Rabinowitsch found the disease among the rats of Berlin, and Dean in 1903 discovered it independently in London, and in a later publication (1905) reported success in transferring the infection by artificial inoculation. Since then rat leprosy has been found by Tidswell in the rats of Sydney, Australia; by Kitasato in Japan; Marchoux and Leboeuf in Paris; and the English Plague Commission observed the disease among the rats in India. Wherry and McCoy found a number of cases among the rats caught in San Francisco, and Krakower and Gonzalez a naturally infected mouse in Puerto Rico.

The proportion of rats infected with leprosy in different localities varies greatly; thus in Odessa and Paris from 4 to 5 per cent; in San Francisco 0.2 per cent; in Sydney only 0.001 per cent; and in Honolulu more than 16,000 rats were examined by officers of the U. S. Public Health Service before a positive finding by Badger in 1935. The fact that the infection is, relatively, so rare in Honolulu suggests that this rodent plays no part in the epidemiology of the human disease.

Leprous rats in a late stage of the disease are usually recognized by the presence of patchy alopecia associated with cutaneous and subcutaneous nodules which may be the site of open ulcers; only in advanced cases are the internal organs affected. The diagnosis is readily confirmed by microscopic examination of a smear from an ulcer or a nodule, which will show the acid- and alcohol-fast bacillus of the disease in enormous numbers, and mostly in the cells. It is doubtful that the bacillus has ever been cultivated.

Currie has shown that rats may infect each other by contact, also that bacilli of rat leprosy may often be demonstrated in the heart's blood of infected rats.

Marchoux (1923) inoculated rats with the spleen tissue from a man with a leprosy-like condition and produced a disease in rats indistinguishable from their spontaneous leprosy. Further studies upon rat leprosy will throw light upon the modes of transmission and control of the human disease.

**Contagiousness.** In the Philippines (Doull and others, 1942), a substantial



proportion of persons exposed to lepromatous leprosy in the household contract leprosy before the age of 25 years, 29 per cent of males and 14 per cent of females. Of persons without a history of family contact, in the areas studied, less than 6 per cent of males and less than 3 per cent of females contract the disease before age. It follows, therefore, that the disease, in the Philippines at least, is of a higher order of contagiousness than has been thought, but probably is much less so than is tuberculosis. Contact with the tuberculoid type apparently does not involve material risk of infection. There is no evidence that the disease is inherited; children born of leprous parents rarely develop the disease if removed at once.

Doctors, nurses, sisters of charity, ward tenders and others directly exposed to leprosy sometimes become infected. Notable examples have been Father Dan of Molokai, Hawaii; Father Bagliolo in New Orleans; Sir George Turner in Pretoria and Mary Reed in India. The influence of exposure is clear in cases among veterans of the United States Armed Forces. Of 32 American veterans of the Spanish American War who developed the disease 19, and of 55 World War I and Korean War veterans, 15 were born in northern states. In World War I, on the other hand, there was little exposure; none of 51 veterans admitted to Carville was born in a northern state.

Geographic location is a dominant factor in the spread of leprosy, although the disease has occurred in every climate. In the United States it propagates chiefly in south Florida, southeastern Texas and southern California. Why leprosy spreads in some regions and not in others remains unsolved.

**Modes of Transmission.** Leprosy is apparently a contact disease, but just how it is caught we do not know. The prevailing notion is that the bacilli invade the body through the skin or mucous membranes. The bacilli may leave the body in sputum or in its secretions or excretions. They are contained in enormous numbers in discharges from broken-down nodules of the skin or mucous membranes. As the nose is often affected, these discharges may be infectious. Even feces and urine contain acid-fast bacilli.

In view of the doubt concerning the way the leprosy bacillus enters the body, the different possibilities deserve consideration. The site of the lesions, the course of the disease and the higher prevalence in the tropics suggest that the bacilli enter through the skin. It is also possible for them to enter through the mucous membranes of the nose or throat, or through the digestive tract. Food has been accused; insects are suspected.

It may be definitely stated that leprosy is not due to the eating of any particular food. Jonathan Hutchinson stoutly maintained that leprosy was due to a fish-bone, but there is no satisfactory evidence in favor of the fish theory, and much against it. One thing is plain, and that is, leprosy is not contracted from any of the known animals, but is an infection which passes somehow rather directly from man to man.

The suspicion that parasitic insects may play some role in the transmission of leprosy has existed for some time, but the evidence bearing on the possible role of insects in the transmission of leprosy is based upon analogy and is largely presumptive. The final verdict will depend upon further studies.

A majority of lepromatous patients at some time in the disease have acid-fast bacilli in their nasal secretions. The importance of the nose in leprosy was brought into prominence at the First International Leprosy Conference in 1897 by the work of Sticker, who made sweeping statements concerning the nose as the site of primary lesion and the danger of nasal secretions in transmitting the disease. J. Selme and Laurans in 1895, Gerber in 1901, Werner in 1902 and Sheroux in 1903 and others have shown the frequency with which the bacilli of leprosy appear in the nasal secretions.

\* There are many acid fast bacilli, and we have no clear criterion to differentiate the bacilli of leprosy, except that it cannot be cultivated on laboratory media.

nasal secretions and the importance of the nose as a site of leprous lesions. Brinckerhoff and Moore, however, who made a careful study of this question in Honolulu, point out that most of the studies upon the importance of the nose in leprosy have been made upon relatively advanced cases. They found the nose frequently the seat of infection when the disease is well developed, but practically never as a primary incipient lesion. If there be a primary lesion of leprosy it has not been discovered. Brinckerhoff's view that nasal lesions are frequently primary has not been confirmed.

Jeanselme in 1914 reported observations supporting the Chinese and Japanese belief that leprosy spreads largely by sexual contact, but there is little evidence to support this view.

It is sufficient for practical purposes to know that the disease appears to be spread by direct contact especially under conditions of overcrowding, particularly where there is close and protracted association between lepromatous patients and young children.

**Prevention.** In view of the unsatisfactory nature of our knowledge of the transmission of leprosy, it is not surprising that our efforts at control and prevention have not been crowned with conspicuous success. The key to the attempts at control of the disease has always been isolation of the patients. That this has not proven highly successful probably is due to the fact that under practical conditions the cases are not brought under observation and isolation until the disease is somewhat advanced. This is to be accounted for by the insidious onset and by ignorance on the part of the patient as to the nature of the early manifestations of the disease and to the disinclination to surrender to health officers since this usually means separation from home and associates.

The defects of isolation as it is practiced have led to certain modifications in the handling of leprosy. Home segregation, in which the patient is confined to his domicile and even then kept from contact with children, and the establishment of outpatient clinics where patients report periodically for examination and treatment, are now advocated.

It is obvious that in countries where the disease shows no tendency to spread, stringent measures are not required such as are desirable in endemic areas.

There is difference of opinion concerning the value of segregation. Sir Leonard Rogers believes that it is effective even when imperfectly carried out; Newman, Hutchinson and others hold that the disease disappeared in Europe despite segregation. The effect doubtless varies with the proportion of lepromatous patients segregated. Segregation in the Philippines probably so far has had no conspicuous effect upon the prevalence of the disease; the results however, are the subject of controversy. There are factors in the control of leprosy not yet understood.

There can be little objection in a country such as ours, where leprosy shows slight tendency to spread, to give a patient his freedom, except in the endemic foci in the Gulf States. There is no more danger from a leprosy patient with clean personal habits, who exercises care concerning the discharges from the lesions, than there is from an open case of tuberculosis of the glands of the neck. The purely nerve cases may properly be given a greater degree of liberty than those with nodular manifestations. The parole system, begun in 1912 in the Hawaiian Islands, is sensible and successful. Those paroled are required to report for examination from time to time.

Under the immigration law aliens with leprosy are excluded from admission to the country. Under Federal quarantine regulations, United States citizens having leprosy upon return from a foreign country may be detained until arrangements can be made for safe travel or isolation, subject to state and local health laws. Aliens who arrive with leprosy, or who are found to have entered the country while



they had the disease, should be reported to the Immigration and Naturalization Service, since they may be subject to deportation.

Practical methods for the control of leprosy in localities in which it shows tendency to spread may be summed up as follows:

1. Educational measures directed toward early recognition.
2. Facilities for specialist consultation and bacteriologic diagnosis.
3. Notification to the local health authority.
4. Immediate isolation of lepromatous patients, preferably in a leprosarium.
5. Home isolation, with clinic supervision, is necessary in many countries.

Dependence must be placed upon educational measures, sulfone treatment, disinfection of discharges, and, wherever possible, removal of young children from the home. Infants should be removed at birth.

6. An examination every six months of all household contacts and close associates to detect new infections at the earliest moment.

**Specific Prophylaxis.** Vaccination with BCG induces reactivity to leprosy and thus may be of value in prevention of the lepromatous type.

**Treatment.** Drugs of the sulfone group, first used in 1941 by Faget and his associates at Carville (Faget, 1946), are rapidly replacing chaulmoogra oil in the treatment of leprosy. Beneficial results are attributed to a radical common to the group, diaminodiphenylsulfone. Prolonged administration is required. After three years only about 30 per cent of patients are negative bacterioscopically, but practically all patients continuing treatment for five or six years show substantial benefit. Experience is as yet too short to judge whether cases are cured or merely arrested.

In appraising the influence of treatment it must be borne in mind that leprosy, particularly of the tuberculous type, is prone to prolonged periods of quiescence and that marked improvement may occur spontaneously, and indeed this may lead on to apparent cure.

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### INFECTIOUS MONONUCLEOSIS

(*Glandular Fever, Pfeiffer's Disease*)

Infectious mononucleosis is a relatively benign acute or subacute infectious disease of unknown cause having a diverse and somewhat obscure clinical pattern. After an incubation period of from 5 to 15 days, the onset is rather abrupt with fever and constitutional symptoms, general malaise, mild prostration and headache. Usually there is sore throat and within two or three days enlargement of the lymph nodes becomes apparent. While the cervical nodes may be especially prominent, enlargement usually affects all the nodes of the body. This gives a lead to the diagnosis, but is not always manifest, particularly in adults. In some cases there may be little or no inflammation of the throat; in others, it may be sufficiently severe

lead to membrane formation. About 15 per cent of cases show a skin eruption at the onset, which has been variously described as purpuric, maculopapular, morbilliform or scarlatiniform. The duration of the fever is commonly not more than five days. The enlargement of the lymph nodes reaches a maximum at the time the fever is subsiding and subsides with convalescence. Recovery is usually complete in from 10 days to 3 weeks, but in some patients it may be a matter of several months. Occasionally, the illness is complicated by jaundice, and in a larger proportion functional tests indicate liver damage (Jordan and Albright, 1950), giving rise to confusion with "infectious hepatitis."

**Laboratory Diagnosis.** As the name implies, a characteristic feature of infectious mononucleosis is a hematologic change. In the early stages there may be a leukocytosis or even a leukopenia. Later, a mononucleosis develops, the total white cell count rising to 15,000 or more, with both a relative and absolute increase in lymphocytes. Some of these are large monocytes, originating in the reticulum of lymphatic tissues, with a peculiar morphology. The discovery in 1932 by Paul and Bunnell that the serum of patients with infectious mononucleosis agglutinated suspensions of sheep cells in high titer provided a test of value in confirmation of the diagnosis. The test for the presence of this heterophile antibody usually becomes positive between the sixth and twenty-sixth days of the illness, most commonly between the twelfth and twenty-first days. It usually remains positive for from two to four months after onset, although this period varies greatly. A sheep-cell agglutination in a dilution of 1:32 or greater with the Paul-Bunnell technic is considered significant. A negative reaction does not rule out the diagnosis, nor does a positive one definitely establish it. If the titer is high enough (1:128 or more), sheep-cell agglutinins in normal serum, in serum from patients with serum sickness and other conditions, can be differentiated by prior absorption with guinea pig kidney and boiled beef cells.

**Prevalence.** Attempts to transmit infectious mononucleosis to rabbits, monkeys, white mice, guinea pigs and human beings have failed. Nevertheless, observations on the occurrence of the disease led to the inference that it is contagious under some circumstances—not as yet well understood. The disease occurs sporadically and in propagated epidemics. Sporadic cases do not appear to be very contagious, for hospitals treat these patients in an open ward without cross infection. Rarely can one case be traced to contact with a preceding case. Since West's report of an outbreak in an Ohio community in 1896, many accounts have appeared of similar epidemics in mental institutions, boarding schools, children's hospital wards, and in military camps. In recent years, infectious mononucleosis has been an important source of admissions to hospitals and infirmaries of colleges and universities. At Dartmouth College it represented 0.74 per cent of the total infirmary admissions (Milne, 1945); at Harvard University 1.5 per cent (Contratto, 1944); and at Yale University 1.7 per cent. At Smith College it accounted for 0.78 per cent of admissions in 1945-46 and by 1948-49 this had increased to 3.4 per cent (Evans and Robinton, 1950). No general seasonal trend is apparent. While the data suggest that transmission may be effected by subclinical or inapparent infections, the evidence in this regard is not entirely clear, owing to the uncertainties of identification by laboratory procedures. When medical students are required to do differential blood counts on themselves, it is surprising how frequently they are found to have mononucleosis and a positive Paul-Bunnell test in the absence of definitive clinical symptoms.

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## TRACHOMA

Because of its progressive disfiguring and incapacitating character, trachoma has always been the most important of ocular infections. It is still a problem of considerable magnitude among the poor neglected populations of Egypt and the Middle East, countries bordering the Mediterranean, Russia and the Orient. In the United States, the incidence of trachoma has never been accurately determined, since the disease is not uniformly reportable. It has been endemic for years in the native population of West Virginia, Arkansas, Tennessee, Oklahoma, Ohio, Kentucky, Missouri and Illinois. This is the so-called "trachoma belt." Cases are by no means limited to this area. New cases of trachoma, exclusive of those among Indians, are shown in Table 5-3, by states of origin as reported to the U. S. Public Health Service in 1937 and 1941. The figures probably do not represent an actual increase in the incidence of trachoma but a better appreciation of its presence and better reporting methods (Forster and McGibony, 1944). The first recorded survey of trachoma among Indians was made by the U. S. Public Health Service in 1911. It was found that 22.7 per cent of a group of 39,231 Indians examined on various reservations in the United States were found to have trachoma. The incidence varied from 68.72 per cent in Oklahoma, the highest, to none found in the Indian Territory, Florida. Incidence throughout the years following maintained a fairly constant average of 18 to 25 per cent. No appreciable progress was made in combating the disease until 1939, although thousands were treated by surgical and medical means. Incubation period is 5 to 12 days, determined by human volunteer experiments.

In the early stages, it is differentiated with difficulty from other forms of chronic follicular conjunctivitis. The first visible evidence of the disease is the presence of follicles beneath the conjunctiva of the upper and lower retrotarsal folds. Slight changes in the upper limbus region make diagnosis possible at this early stage. Later, follicles may be found on the palpebral and the bulbar conjunctivae. The inflammatory process involves the cornea, particularly of the upper limbus region. During this acute stage the exudate may be abundant and mucopurulent in character. This becomes scanty as the process subsides over the course of several weeks, but conjunctival and corneal cicatrization may progress. In the advanced stage, deformity of the eyelids with cicatricial entropion may develop and vision be impaired by the scar formation from pannus (extension of blood vessels from the upper limbus downward into the cornea) and recurrent ulcers. The condition may become arrested at any stage and healing take place.

**Etiology.** The disease has been transmitted experimentally to human beings and other primates, notably apes, baboons and monkeys. Unfortunately, the disease in experimental animals is self limited, appears only as a follicular conjunctivitis and does not develop pathologic changes characteristic of human trachoma, i.e., pannus and scar formation. In 1907, Halberstaedter and Prowazek discovered intracellular clumps of minute bodies in tissue scrapings derived from cases of trachoma studied in Java. They thought that the structures they had found were the etiologic agent of trachoma.

In 1934, Thygeson concluded that the HP inclusion bodies represented intracellular colonies of a virus in different stages of development. Later, Thygeson and Proctor proved that the virus of trachoma was readily filtrable through colloidal

Table 5-3. Cases of trachoma reported to the U. S. Public Health Service by the State Health Officers  
(Totals of the monthly reports)<sup>a</sup>

Division and State	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948
New England	40	28	18	0	2	18	20	3	15	6	1	1	8	3
Middle Atlantic	29	21	20	12	5	6	9	2	7	3	2	2	1	0
East North Central	1262	1668	518	620	369	386	390	310	218	212	79	42	17	16
Illinois	1211	1624	502	587	291	323	284	280	186	179	49	33	10	9
West North Central	674	554	530	536	507	546	614	682	859	800	766	548	548	658
Missouri	508	490	476	471	429	443	575	636	674	690	710	425	500	592 <sup>b</sup>
South Atlantic	36	14	7	53	14	29	17	40	21	3	1	1	1	71
East South Central	236 <sup>c</sup>	492 <sup>c</sup>	189 <sup>c</sup>	87	182	378	191	60	86	80	77	142	46	87
Tennessee	177	394	116	24	11	144	37	6	5	2	1	2	4	1
West South Central	96	79	143	180	685	2011	3224	551	773	831	722	798	531	528
Arkansas	26	19	29	87	205	1045	1908	430	594	506	390	385	234	102
Oklahoma	68	58	106	72	392	763	1166	0	79	145	173	287	200	306
Mountain States	465 <sup>d</sup>	524 <sup>d</sup>	635 <sup>d</sup>	677	626	917	851	1024	624	582	271	453	408	763
Arizona	389	407	302	404	511	595	800	961	410	466	219	329	225	478
Pacific States	272	568	282	390	272	266	191	4	175	122	45	56	43	55
California	187	476	243	384	257	235	156	0	130	77	40	32	41	33
TOTAL	3110	3948	2342	2555	2662	4557	5507	2676	2778	2639	1964	2043	1603	2186

<sup>a</sup> No rep'ts from Kentucky and Utah, 1935, 1936 and 1937.

<sup>b</sup> Six months, July-December.

<sup>c</sup> Kentucky not included.

<sup>d</sup> Utah not included.

From WHO, Epidemiological and Vital Stat. Rep't, Nov.-Dec., 1949.



membrane. The virus dies rapidly outside the human body, and is easily destroyed by heat. Attempts to cultivate it in tissue culture and on embryonated hen's eggs have been unsuccessful. Studies of Rake and others (1942) suggest that antigenic components are shared between the virus of trachoma and the members of the lymphogranuloma-psittacosis group of agents. Laboratory confirmation of the diagnosis is based on the finding of typical cytoplasmic inclusion bodies and on characteristic cytologic changes in expressed follicular material (Julianelle, 1938).

It is believed that the infectious agent is transmitted from eye to eye by means of contaminated fingers or articles. In sporadic cases, it is often impossible to trace a source of infection. In countries where trachoma is widely prevalent it may be acquired during infancy. Its transmission is probably facilitated in these areas by the occurrence of epidemics of acute infectious ophthalmias due to other causes. The prevalence of trachoma is associated with poor hygienic conditions, crowded living and poor nutrition.

**Control Measures.** Prior to 1938, trachoma was treated by a combination of medical and surgical means. Where this was available it brought relief from symptoms and arrested the progress of scarring. However, these measures were ineffective in reducing the incidence of the disease. A number of workers have reported favorably on the use of sulfonamides, given orally, parenterally or locally (Thygeson, 1945). Under sulfonamide therapy the prognosis of trachoma has changed entirely, and in early cases cures can now be expected in a matter of weeks. It is ineffective, however, in the late stages, when surgical intervention becomes the only means of relief. In the United States prior to the introduction of sulfonamides in 1938, the extension of antitrachoma campaigns conducted in the Indian schools were showing only partial success; as a result of sulfonamide therapy instituted at that time, the incidence of the disease has been strikingly reduced as indicated in Table 5-4.

Recent reports indicate the tetracycline antibiotics or chloramphenicol are equally effective. When active lesions exist, children should be excluded from school.

Table 5-4. Examination of school children for trachoma

Fiscal Year Ending July 1	Number Examined	Positive Trachoma	Incidence Per Cent
1937	39,273	8,978	22.9
1938	41,685	8,514	20.4
1939	44,235	8,970	20.3
1940	53,580	8,379	15.6
1941	56,794	4,896	8.6
1942	38,761	2,696	6.9
1943	34,419	1,859	5.4

From Forster and McGibony, *Am. J. Ophth.*, 27:1111.

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# 6

## ARTHROPOD-BORNE DISEASES

### MALARIA

GILBERT F. OTTO, Sc.D.

Malaria is really a closely related group of diseases caused by four different protozoan species, *Plasmodium vivax*, *P. ovale*, *P. falciparum*, and *P. malariae*. Although these diseases differ one from the other biologically, pathologically, clinically, and epidemiologically, there is a common core of similarity among them so that the group may be conveniently discussed as a unit. The characteristic clinical manifestations of malaria are those resulting mainly from the recurrent, intermittent, remittent, destruction of erythrocytes or the sequelae of such destruction.

Although malaria has been known since antiquity and the early Greeks and Romans appear to have associated "the intermittent fevers" with the swamplands during the summer, it was not until the latter part of the past century that there was any definite clue to the nature of that association. Laveran, in 1880, was the first to describe *Plasmodium* in the blood of malarious patients, and shortly thereafter Manson developed his mosquito theory of transmission; it seemed to Manson a reasonable postulate that mosquitoes became infected by feeding on the malarious patient and then disseminated the infection in the water as they died. Under Manson's stimulus Ross, in 1897, 1898 and 1899, demonstrated not only that mosquitoes became infected by feeding upon malarious individuals but that the parasite underwent an obligatory development (sporogony) in the mosquito host and, transcending Manson's theory, demonstrated in the case of a bird malaria that it was thereafter transmitted to the next individual as the culicine mosquito fed again. Ross's discoveries were quickly confirmed by a number of workers, including Koch, who had early subscribed to the "mosquito theory." Bignami, Bastianelli, and Grassi not only confirmed Ross's findings but worked out further details of development of the infection in the mosquito and, in 1898, were the first to actually demonstrate the transmission of malaria to man by the bite of the infected anopheline mosquito. Manson, in 1900, produced the infection in volunteers in London who were bitten by anopheline mosquitoes which had been infected by Bastianelli in Italy, and, in the same year, three of Manson's colleagues lived in a screened hut during the malaria season in the Roman Campagna without contracting malaria, while the local population in unscreened houses suffered severely.

Thus, by the turn of the century, it seemed simple enough to eradicate or, at least, reduce and control "the scourge of the tropics" by the simple expedient of eliminating or reducing the mosquito population. Despite some skepticism, plans were enthusiastically discussed, and some were actually launched in various parts



of the world. The outstanding early success was that which attended the efforts of Gorgas and his staff. Although the daring and thoroughness of this program is commonly remembered and cited in relationship to the dramatic effect upon yellow fever, it was equally successful against malaria. First in Havana, Cuba (between 1901 and 1904), and later in the Panama Canal Zone, the annual attack rate of approximately one case per inhabitant dropped in a few years to a few dozen per 1,000 as the transmission of malaria by *Anopheles albimanus* was interrupted. Larval breeding places were filled, drained, or periodically treated with oil; adult mosquitoes were killed in houses and known cases were isolated behind screens for treatment. In the Federated Malay States, Watson was equally successful in eliminating malaria by destruction of anopheline breeding sites. Clearing the jungle and draining the swamplands near the town of Klang eliminated *A. umbrosa* and freed the town of malaria.

Elsewhere in the world various lesser degrees of success, and even failure, resulted from similar efforts. In the meantime, malaria in Europe was gradually receding to its Mediterranean stronghold without any appreciable attempt at control, leaving in its wake isolated pockets of persistent malaria, as, north Holland, which showed no signs of yielding to the most persistent frontal attack by health agencies. Anopheline reduction in north Holland had no demonstrable effect upon the prevalence of malaria, and, conversely, elsewhere there was no discernible diminution in anopheline mosquitoes associated with the rapidly receding malaria. Experiences in World War I were discouraging. Whole armies, both Allied and Teutonic, were immobilized by malaria in southeastern Europe during 1916, and returning personnel after the war provided the seed for severe epidemics of malaria in northern Europe. The disease even extended into the Arctic, at Archangelsk. Again, however, it spontaneously disappeared from some areas and gradually receded southward through most of Europe; and again without any evident decrease in the anopheline population. Thus, the enigma of "anophelism without malaria" became a challenge, almost a battle cry, to the frustrated malariologist.

Even the apparent success of the antilarval measures and screening of houses in some parts of the southern United States was not without its ambiguities. The League of Nations Malaria Commission, which visited the United States in 1926, noted that the disease had a definite downward trend, had already disappeared from large areas, and seemed to have reached a point at which it was of very little importance as a cause of sickness and death before the initiation of antimosquito campaigns. As in Europe, there was no appreciable diminution of *Anopheles* in the areas where malaria had disappeared and the decline of the malaria rate was not accelerated in local situations with intensified efforts at mosquito control.

Furthermore, it was soon recognized that conditions in Europe and North America were vastly different from those in many tropical areas and it became equally evident that within the tropics there were marked differences in the epidemiology of the disease; that, for instance, rural malaria in the foothills of the Philippines must be handled differently from urban malaria in Calcutta. Nevertheless, the net result was to cast a great deal of doubt on the value of the early magic formula "reducing malaria by antimosquito measures." Thus, the Second General Report of the Malaria Commission of the League of Nations in 1927, while recognizing the "limited value of antilarval measures," stressed the value of "sanitation" and

ect measures. James, Swellengrebel, and others advocated the liberal use of quinine which would reduce the duration and severity of the illness, although it could not be expected to reduce the attack rate. The destruction of mosquitoes, particularly swatting blood-engorged mosquitoes, resting in houses was the only antimosquito measure which appeared to offer any prospect of immediate value in control, at least in Europe. It was pointed out that bonification, i.e., improved housing, farming practices, and general living, had done more in the temperate zones to reduce malaria than all the antimosquito measures combined. The resulting confusion was aptly discussed in 1937 by Hackett in the first chapter of his book (*Malaria in Europe*) under the title "A House Divided." In 1936, Russell noted that, although measures were available for malaria control in organized communities, such as cities, "the longer one observes malaria in the tropics the more one is forced to conclude that, so far as the average rural areas are concerned, the problem of control is still unsolved."

The League of Nations Malaria Commission in its several reports during the 1920's and 1930's echoed the sentiment of some malariologists that the discovery of the insect vector of malaria had not solved the problem of malaria control; that intensified research on all phases of malariology was still needed to provide the answers. Investigations were already in progress the world over, and the attack continued with renewed vigor through the late 1930's, World War II, and the post-war period. The life history of the parasites and their bionomics in both the insect and vertebrate hosts and the host responses to infection have been critically studied in the laboratory; the mode of attack of old and new therapeutic agents against various stages of the infection, the basic pharmacology of these agents, and their relative values in mass treatment and suppression have been investigated. Of fundamental importance in control has been the detailed information garnered on the recognition and biology of different species, and subspecies, of *Anopheles*, with particular reference to their relative roles in transmission of malaria. Evaluation of control projects and field studies over the past half century helped significantly in clarifying the confusion.

It is safe to say that in the half century since the discovery of the mosquito transmission of malaria the pendulum has completed an arc from (1) Ross's and Manson's "malaria control through destruction of mosquitoes" and Grassi's "modification" through the destruction of *Anopheles*, (2) to the point where, in 1927, the League of Nations Malaria Commission "considers the treatment of malaria-infected persons to be one of the most important measures even from the point of view of prevention," (3) back to major emphasis on antimosquito measures. In the intervening years the formulae have been further sharpened to "species control" and "species eradication." Thus, the attack is directed not against anophelines in general but against that species, or those species, which within a given area are most likely to be the principal vectors of malaria. Furthermore, with the development of effective use of residual spraying, antilarval measures have been largely abandoned in favor of attacking the adult female in human habitations where it commonly transmits malaria.

**Distribution of Malaria.** Despite the fact that significant malaria control, and even eradication, has been accomplished in some areas, malaria still remains the single most common cause of debilitation and death throughout the world. In addi-



tion to the early successes in eliminating malaria in local situations such as Havana, Cuba, the Panama Canal Zone, the town of Klang in Malaya, from the "fish po areas" of Java, and the more recent elimination of "*gambiae*-transmitted malaria" from Brazil, the past decade has seen similar successes over much wider geographical areas. The natural recession from "bonification" accompanied by intensive control procedures appears to have eliminated endemic malaria from the United States (Symposium on Malaria Eradication, 1951). Measures of attack have all eliminated malaria from Chile, British Guiana, Venezuela, Sardinia, and parts of western Europe.

Nevertheless, malaria is still one of the important health hazards in so many areas of tropical America, southeastern Europe, and Asia Minor. In much of tropical Africa, southern Asia from India to China, and the western Pacific Islands as far north as Formosa, malaria continues undiminished by control measures. It has been estimated that over 300,000,000 people still suffer from malaria and over 3,000,000 die annually from the disease or its complications. Thus, between 5 and 10 per cent of the world's population appear to suffer from malaria. It is still the most prevalent disease in many of the tropical areas of the world and in the temperate zone of Asia.

Malaria is absent, and apparently has never occurred, due to the absence of anopheline mosquitoes, in the North Pacific east of the Philippines and the South Pacific east of the 175th meridian. This includes such groups of islands as Maria, Caroline, Marshall, Gilbert, Ellice, Fiji, Samoa, Tokelau, Hawaii, and Marquesas. In the Western Hemisphere such tropical islands as the Bahamas and the northern Leeward Islands are similarly free of anophelines and malaria.

**Life Cycle of the Malaria Parasite.** The sexual development (sporogony) of the plasmodia of man is completed with resulting multiplication only in anopheline mosquitoes.\* Asexual multiplication (schizogony) takes place in two distinct phases in man, the commonly known development in the red blood cells and the little known but apparently more basic development in other tissues (the so-called erythrocytic or E E stages). The sexual cycle is initiated in man with the product of the male and female elements (microgametocytes and macrogametocytes).

The gametocytes, ingested with the blood meal, undergo maturation within a few minutes in the stomach of the mosquito. Each macrogametocyte produces a macrogamete, or female cell, which is fertilized by one of the (2 to 8) microgametes or male elements, which escape from the microgametocyte. The resulting fertilized cell (zygote) soon elongates into a motile ookinete which penetrates the stomach wall by slow amoeboid movement and comes to lie under the parietal lining of the stomach, where it rounds up and secretes a protective membrane to become an oocyst. Within the oocyst, nuclear and cytoplasmic divisions produce a number of sporoblasts which, in turn, develop rosettes of sporozoites. A few hundred to several thousand sporozoites are thus produced which upon rupture of the oocyst migrate through

\* So far as is known, the sporogony of other species of mammalian plasmodia also takes place only in anophelines. The one report of the development of the plasmodia of man in culicine mosquitoes has never been confirmed and appears, at any event, to have no epidemiological significance. However, the avian plasmodia appear to be commonly, if not principally, transmitted by culicine mosquitoes, although a number of avian species readily develop in anophelines.

body cavity. Within two to three weeks, depending upon a number of factors such as temperature, humidity, and species, the sporozoites arrive in the salivary glands ready to infect the next human the mosquito bites.

The early development in man is entirely unknown but it is clearly established that the *sporozoites do not develop in the red blood cells*. The pioneer work of Huff with *P. gallinaceum* of chickens has shown that the sporozoites develop into large schizonts in cells of the reticulo-endothelial system and this has subsequently been found by a number of workers to be the case with several other species of malarian plasmodia. Huff and Colston have shown that the merozoites resulting from the second generation of these pre-erythrocytic or exoerythrocytic schizonts are capable of penetrating erythrocytes and developing into the well known erythrocytic schizonts. Thereafter, both erythrocytic and exoerythrocytic schizogony may continue.\* Whereas the erythrocytic schizonts produce a dozen or two merozoites the pre-erythrocytic schizonts produce from less than 50 merozoites in *P. relictum* to over 500 in *P. gallinaceum*.

Shortt and his co-workers (1951) have reported very large pre-erythrocytic schizonts of *P. falciparum* in the parenchyma cells of the liver as early as the fourth day after infection and of *P. vivax* as early as the sixth day. The continuity between the sporozoites and these reported schizonts in the parenchyma cells and between these forms and the blood stages have not been traced directly. Certain questions have been raised which will undoubtedly be resolved by further experimental observations. Regardless of the details, it seems certain that these or similar pre-erythrocytic stages occur and account for the failure of attempts at chemical prophylaxis. Shirley has failed to demonstrate parasites of *P. falciparum* in the general circulation in less than six and a half days after the mosquito bite and *P. vivax* in less than seven days, even by the subinoculation of 200 ml. of blood into susceptible volunteers. Even in very heavy initial infections parasites cannot be detected in the blood by the usual technics (examination of either thin or thick blood smears) until some days later.

It appears likely that the exoerythrocytic development of *P. falciparum* and *P. ovale* is much more limited than is the case with the other two species. Since relapses are uncommon with the two former species it is possible that exoerythrocytic schizogony often terminates during the primary parasitemia. With both *P. vivax* and *P. malariae*, however, the exoerythrocytic schizogony appears to continue for years and to be the source of the recurring parasitemia with resulting clinical relapse.

Each cycle of schizogony in the red blood cells requires about 48 hours for *P. vivax* and *P. ovale*, 24 to 48 hours for *P. falciparum*, and 72 hours for *P. malariae*. Each schizont of *P. vivax* produces 12 to 24 (commonly 16) merozoites; *P. ovale* about 8, *P. falciparum* 8 to 24 (as high as 32 have been reported), and *P. malariae* about 12 (commonly 8). The merozoites of *P. vivax* and *P. ovale* have a predilection for reticulocytes and usually invade and develop in these large young cells. Schüff-

\* Huff and Colston have termed the first generation of pre-erythrocytic schizonts, which develop from the sporozoites, *cryptozoites* and the second generation *metacryptozoites*. The exoerythrocytic schizonts which may be initiated later by merozoites from the erythrocytic cycle they term *phaenerozoites*. The relationship between phaenerozoites and continued generations of metacryptozoites is not clear.



ner's dots are characteristically seen in the parasitized cells in these infections, appearing earlier and more dense in *P. ovale* infections. *P. falciparum* and *P. malariae* show no such marked preference for reticulocytes and are more commonly seen in mature normal-sized erythrocytes; Schüffner's granules are not associated with the species. With all species, except *P. falciparum*, all stages of erythrocytic schizogony from the newly established merozoite or young trophozoite (ring stage) to the mature and rupturing schizont are seen in the red blood cells in the peripheral circulation. Only the young stages (rings) of *P. falciparum* are characteristically seen in blood smears; developing forms and mature schizonts are seen only in hepatic infections, commonly when the patient is in a critical condition. Ordinarily, the erythrocytic schizonts in this disease may be in the vascular bed of internal organs or adherent to the vascular wall and do not flow with the blood.

Under circumstances not clearly defined, some of the merozoites develop into gametocytes rather than schizonts. This occurs both early and late in the infection but, in general, the ratio of gametocytes to schizonts increases in the course of infection. It is commonly assumed that gametocytes develop from merozoites of erythrocytic schizogony but it has not been established and there is evidence in *P. gallinaceum* infection that they develop from merozoites arising from exoerythrocytic schizogony.

**The Disease.** The incubation period varies, not only with the species and strain of malaria, but with the number of sporozoites in the infecting dose. In general, however, the incubation period of *P. falciparum* is around 9 to 11 days, *P. vivax* and *P. ovale* about two weeks, and *P. malariae* three to four weeks. Parasitemia (patency) detectable on thin or thick smear examination, usually occurs a day or so before the first clinical evidence of disease. Prodromal signs include headache, general malaise, and a temperature of 100° F or higher followed in a day or two by the typical malarial paroxysm. With *P. vivax*, *P. ovale* and *P. malariae* there is usually an intermittent fever with the paroxysms sharply defined, approximately every 48 hours for the first two species and 72 hours for the latter. The mu-  
described rigor or subjective feeling of chills is associated with a rapid rise in temperature which may reach 104° F or even higher in less than an hour after it goes above 100° F. Chills are reported to occur in well over half of the paroxysms; when the temperature is less rapid there may be no evidence of chills. The temperature is above 100° F for 9 to 12 hours. In general, the temperature is highest but the febrile period shorter when it rises rapidly enough to produce chills. *P. falciparum* characteristically produces a remittent fever. Anemia develops in malaria most rapidly in *P. falciparum*, often with a net loss of 60 per cent of the erythrocytes scarcely over a week. Splenic enlargement is a constant characteristic of all malarias. In the primary attack, the acute splenic tumor may even noticeably fluctuate in size with paroxysms. In chronically repeated malaria, or repeated exposure to malaria, the spleen will become fibrosed and may ultimately become permanently enlarged. The many reports of reduced liver function in both primary and relapsing malaria may, perhaps, be explained by the reports that the pre-erythrocytic stages develop in the liver.

There are many localized manifestations of malaria which are a source of confusion. These are usually associated with *P. falciparum* infection. Among these are cerebral malaria, and algid, or "cold," malaria, which is frequently associated with

sclerotic manifestations, are often associated with fatal malaria. Cerebral malaria is particularly associated with a high mortality rate. Uncomplicated infections with the other three species rarely prove fatal but *P. vivax* is associated with protracted disability and is a significant contributory cause of death.

Cachectic malaria is associated with repeated attacks of malaria in individuals suffering from some concurrent debilitation, frequently malnutrition, hookworm, or both.

*Blackwater fever or hemoglobinuric fever* is a complication in highly malarious districts. It, too, is associated with *P. falciparum*. It occurs only after repeated attacks of malaria over a period of a year or two. The red cells become friable and intravascular hemolysis occurs. The renal tubules are blocked and the kidney pathology appears to be a secondary rather than a precipitating cause. Inadequate treatment of recurring malaria appears to be an important precipitating cause.

**DETECTION OF MALARIA IN THE INDIVIDUAL.** The final diagnosis of malaria usually rests upon the finding of the malaria parasites in the peripheral blood. For this purpose both the thick and the thin blood smears are of value. The regular thin smear used in differential leukocyte counts is of value because the species of parasite can be more easily determined when the cell and the parasite within it are both intact. Any of the Romanovsky stains are suitable, but malariologists generally prefer Giemsa's or Leishman's stains since they give more critical staining of the parasites than some of the other blood stains. Thick smears have the advantage of concentrating the blood and thus increasing the chance of finding parasites. Such a smear is usually made about the size of a dime from blood which "wells up" freely from a finger prick. The blood should be stirred a few seconds with a corner of a glass slide and should finally be about two to six cells deep. If the smear is too thick it will chip off on drying. The blood cells may be lysed and the parasites stained at the same time by immersing the dried smears for 45 minutes to an hour in a 1:50 dilution of Giemsa's stain buffered at pH 7.0 to 7.2. Recently, Donaldson and Crooke (1950) have shown that some parasites will be washed off these slides if they are immersed vertically, and will float up to the surface film where they may lodge on other slides stained at the same time or later. Thus, when many slides are stained at the same time or in rapid succession it is desirable to add a few drops of Triton X-30 (30 to 33 per cent Triton X-100) to reduce the surface tension. When only a few slides are stained at a time it may be simpler to lyse the cells in fresh distilled water and thereafter flood the smear with concentrated Giemsa stain.

Field's method of staining thick smears is more rapid and is beginning to find favor in some quarters. The blood cells are lysed by immersion for a few minutes in distilled water and then the parasites are stained by immersing the smear in a solution of Azur-B for a second and then for the same time in eosin. Recent modifications include reversing the order of staining. Excellent smears are obtained by experienced personnel but the results are less certain in the hands of inexperienced technicians.

Parasites are not continuously present in the peripheral blood even during the primary attack and may be much more sparse during relapse. Thus, in cases of suspected malaria it may be necessary to examine as many as two or three smears taken at 12-hour intervals before parasites are demonstrated.

Parasites may be found in bone-marrow smears but the technic is apparently



not sufficiently more delicate than the use of thick smears of peripheral blood justify it as a routine procedure.

Numerous attempts have been made to develop a serological test for malaria without significant success so far. It may be noted, however, that serological tests for syphilis may be positive during the primary attack of malaria or even late in incubation period of malaria in nonsyphilitics.

**DETERMINING THE INDICES OF PREVALENCE.** Morbidity and mortality records and even less well defined history of malaria can serve as a preliminary guide to the scope of the problem. A more definite indication of the problem and evaluation of control procedures, however, is obtained by direct examination. The two indices which are most useful for this purpose are the Spleen Index and the Parasite Index. The two together give a higher figure for malaria prevalence than either alone. The best correlation between the two indices is obtained from young children during the season of greatest transmission and the poorest in adults during the off-season. Evidence on the extent of the malaria problem can be obtained by determining spleen rate and parasite rates in any and all age groups. However, neither rate in the adults of the indigenous population provides a satisfactory measure of the amount of current transmission. Children, particularly those from two to five years of age, provide a better measure of current transmission. In the temperate zone these rates should be obtained in the summer. In the tropics, it may be desirable to obtain such rates periodically to determine whether or not there is a marked seasonal change in transmission rate.

The spleen rate can be more rapidly obtained than the parasite rate. A quantitative measure of spleen size in children will be of further value in determining the degree of malariousness. Hackett and Russell appear to prefer the following grades as a measure of spleen size.

- 0—Normal, nonpalpable.
- 1—Palpable on deep inspiration only.
- 2—Palpable on normal inspiration, not projecting more than half way from costal margin to a horizontal line through the umbilicus.
- 3—Projecting to the level of the umbilicus.
- 4—Projecting half way from the umbilicus to a line through the symphysis pubis.
- 5—Projecting lower than those in group 4.

Since the limits placed on the classes defined above are not standardized or universally accepted, it is important to record a definition of classes used. Boyd, for instance, would insert a class between the above classes 1 and 2, i.e., palpable on normal inspiration but not projecting below the costal margin; he would, however, combine the above classes 4 and 5 into one class.

A value for the average enlarged spleen (AES) is obtained by multiplying the number of spleens in each class by the class number and dividing the sum of the products by the number of individuals examined. Russell favors the use of both the AES value and the percentage of persons with enlarged spleens as a combined spleen index. Regardless of what method of computation is used, it is desirable to record the number (or percentage) of spleens in each class.

Splenic enlargement occurs with a great many infections and with some degenerative diseases but, for the most part, these possible complications do not serio

interfere with the use of the spleen size as an index of malaria within endemic areas. However, such diseases as kala azar, bartonellosis, and schistosomiasis may produce efficient chronic enlargement of the spleen to complicate the picture. Thus, if for any other reason, it is desirable to determine the parasite rate on at least a portion of the juvenile population during the season of most active transmission. The examination of blood smears for parasites has the further advantage of permitting the determination of the species of plasmodia involved.

**Factors in Transmission.** The older concept that malaria resulted from the presence of mosquitoes and human gametocyte carriers, or the refinement that it resulted from anopheline mosquitoes, human gametocyte carriers, and susceptible humans, does little more than define the minimum requirements for active transmission of the disease. The malaria problem of a community, both the level of endemicity and the frequency and severity of its epidemics, is the function of a variety of often conflicting dynamic forces. Russell in 1931 expressed the complexity of these interacting forces in a formula:

$$(x + y + z) \text{ bepti} = \text{malaria prevalence}$$

where:  $x$  = the human gametocyte carrier

$y$  = the anopheline vector

$z$  = the susceptible human or human victim

$b$  = bionomics of man and the species of *Anopheles* in the area

$e$  = the influence of environmental factors

$p$  = *Plasmodium*, species and strains

$t$  = treatment and/or other attempts at control

$i$  = the level of immunity, racial or acquired

For a complete and detailed discussion of these various factors, the reader is referred to one of a number of monographs and books on malaria.

**BIONOMICS OF ANOPHELINES.** The bionomics of the mosquito vector continues to be the focal point in considering attempts at eradication or control of malaria. Each species of mosquito has fairly well defined food preferences, flight habits, and requirements for breeding and larval development. In some cases, forms which are closely related taxonomically, even different varieties of the same species, may differ in one or more of these characteristics. Thus, to fully appreciate the role of a given species or subspecies of anophelines in malaria transmission, and thus the best method of attack, one must know the biological requirements of that form. Probably most, if not all, of the approximately 200 species of *Anopheles* are susceptible to infection with human malaria and the gametocytes are capable of development within them when taken in with a blood meal. While all species of *Anopheles* appear to be susceptible to malaria they probably are not equally susceptible, and there is evidence that even within a species genetic strains of greater or lesser susceptibility may be developed. Nutrition may also influence susceptibility. Epidemiologically, however, these factors appear to be of minor importance in comparison with the question of whether or not they have the opportunity to feed on man, and avail themselves of that opportunity. This factor alone limits the dangerous malaria transmission to about two dozen species of *Anopheles*.

A number of anophelines which have been shown experimentally to be potential vectors appear to play no such role in nature because they prefer animal to human



blood. Thus anthropophilous anophelines, i.e., those which prefer human blood and under comparable conditions, much more effective vectors than zoophilous species. Since anophelines usually bite at night, the most efficient vectors are those anthropophilous species which come into human habitations, feed at night, rest in dark corners during the day and remain or return to transmit the infection from one member of a family to another and from one family to another. *A. darlingi* is one of the most domestic of all the anophelines and, because of this fact, can maintain endemic malaria at lower mosquito densities than most other species; certainly it is the best vector in the Western Hemisphere. An anopheline which feeds indifferently on man and animals may be an important vector when present in large numbers when animal food is not abundantly available or under other specialized circumstances. Even a zoophilous mosquito may transmit malaria when its abundance exceeds the opportunity for feeding upon animals. Malaria in central Europe at the turn of the century, and again after World War I, was apparently transmitted under such circumstances by the zoophilous *A. maculipennis*. Similarly, the transmission in the United States has been by *A. quadrimaculatus*, which may be classified as a zoophilous species or, at least, as an indifferent feeder on man. *A. pseudopunctipennis* which occurs in the Pacific areas of the Americas from the United States to Chile and the Argentine is zoophilous throughout most of its range and, thus, of little or no concern in the transmission of malaria, but in certain Andean valleys in South America and in part of Mexico, it more commonly frequents human habitations and, thus, is a malaria vector in those areas. A rather different situation is seen in north Holland where a normally zoophilous species (*A. atroparvus*), when trapped in the houses with the onset of cold weather, transmits malaria in the late autumn and early winter.

The normal flight range of mosquitoes from breeding sites in search of blood meals limits sharply the extent of the malaria around waters in which the larvae develop. Most of the *Anopheles* do not ordinarily fly much beyond a half mile or a mile from breeding habitats.

Each species of mosquito has its own preferred breeding sites, often very restricted, which, together with the limits of the flight range of that species, limits the area over which it transmits malaria. Until the advent of the attack on the adult mosquito, particularly with residual sprays, the bionomics of the aquatic stages was of primary concern to the malariologist in planning the antilarval measures. We are not yet prepared to totally disregard these aspects of malariology but it will be sufficient to indicate some of the different types of habitats in which the larval stages of various *Anopheles* develop. Most anopheline species, like *A. quadrimaculatus* in the United States, prefer sunlit or partially sunlit fresh waters, usually shallow pools or shallow margins of larger bodies of water. However, almost every type of water is used by one or another species, from large open brackish water or sea water lagoons (*A. sudaicus*), or densely shaded jungle morasses (*A. umbrosa*), to margins of foothill streams (*A. minimus*, *A. fluviatilis* and others), wells and cisterns (*A. stephensi*), and small collections of waters held by growing plants (*A. bellii* and *A. cruzi*). Others (such as *A. gambiae* and *A. albimanus*) utilize a wide variety of types of water, ranging from temporary rain waters, even those in hoof prints, to large bodies of water. Several species (including *A. albimanus*) are found in both fresh and brackish waters.

The distribution, habitat of the aquatic stages, food preferences of the adult female, and relationship to malaria of some of the more important vectors is summarized in Table 6-1. Many species not included in this table may be vectors of importance in local areas or may be vectors of secondary importance in highly endemic areas.

**THE BIONOMICS OF MAN.** The history of malaria is to a large extent the creation by man of conditions essential for the increase in the density of potentially dangerous anophelines. The history of attempts at control are replete with accounts of efforts to eliminate or obviate these man-made conditions. While this is hardly unique for malaria, it often is so clearly illustrated as to serve as an example of how man creates his own disease conditions. It is true, however, that naturally occurring factors in human biology, beyond the immediate control of man, may and do influence the epidemiology of malaria. The effect of race may be subtle but real. The Negro race is partially or completely refractory to most strains of *P. vivax*, usually suffering little from the infection and, in general, are not good carriers of gametocytes. On the contrary, since they suffer so little from the infection, some may become gametocyte carriers without ever being suspected of that role. Negroes may be even more potent carriers of gametocytes of *P. falciparum*. Age, perhaps, more than race, has its influence on the epidemiology of the disease. Evidence has been presented in a number of areas that children maintain a much higher gametocyte count for a much longer period after recovering from the clinical effects of the disease than do adults of any race (Swellengrebel and De Buck, 1938). There is no evidence that any intrinsic factor related to sex influences the course of malaria but in specialized circumstances habits and activities may bring one sex into greater contact with the mosquito vectors.

However, in general, man influences the course of malaria in a community in his normal activities by the manner in which these activities create or reduce mosquito densities, and afford opportunity for the mosquito to feed on man. Thus, in the colonization of the Western Hemisphere, the forests were cleared, thus exposing the margins of lakes and ponds to sunlight. Ponds were created by excavations and by damming streams, and even by partial filling and incomplete draining of swamp-lands for water supplies or water power. Incidental ponds were created in gravel pits, and borrow pits along highways and railways. The opportunities were thus multiplied many fold for the breeding of *A. quadrimaculatus* from the Atlantic Coast to the Rockies and for *A. freeborni* on the West Coast. To an appreciable degree the human habitations were built individually or in village or city groups around these impoundments. Accordingly, malaria followed the settlers across southern United States and northland on the East Coast to upper New York and New England, up the Mississippi Valley to North Central United States, and on the West Coast as far north as Oregon. Northern soldiers returning to their homes from the southern campaigns after 1865 contributed their supply of gametocytes to help reseed the northern areas.

With continued development of agriculture and increased use of land, without any attempts at specific control, malaria gradually receded to the more favorable southern climates. It is difficult to evaluate the role of any specific measure but it seems probable that continual clearing and draining with tilling of the soil eliminated many water collections, the increased amount of livestock diverted some of the



Table 6-1. Some of the more important anopheline vectors of malaria  
The most efficient vectors are marked with an asterisk (\*)

Species	Habitat of Aquatic Stages	Distribution and Relationship to Malaria
<i>A. quadrimaculatus</i>	Almost exclusively in sunlit or partially shaded permanent types of pools or margins of larger bodies of water such as ponds, lakes, or even slow moving rivers with a cover of vegetation or flotsam to protect them from predators. Acid waters, such as swamp waters, are unsuitable.	East coast of Mexico to New Hampshire, west through Ontario to Minnesota. A zoophilous species but, when abundant, transmits malaria effectively. The only significant vector in the eastern half of the United States.
<i>A. pseudopunctipennis</i>	In sunlit pools and in stream beds, especially those with surface mats of <i>Spirogyra</i> or other algae.	From southwestern United States to northern Chile and Argentina. A zoophilous species in most of its range but, when abundant, transmits malaria. A vector in parts of Mexico and in certain Andean valleys of South America.
* <i>A. darlingi</i>	In clear fresh shaded or partially shaded waters or lagoons, overflows, or marshes, often among matted vegetation.	Southern part of Mexico, Guatemala, Honduras and South America east of the Andes southward to Argentina. This is one of the most domestic and anthropophilous species, particularly in Brazil, Venezuela and the Guianas where it constitutes one of the world's most dangerous malaria vectors.
* <i>A. albimanus</i>	In a wide range of sunlit waters fresh, stagnant, or brackish; in temporary rain pools, ponds, margins of streams, and even among the floating mats in larger, deeper bodies of waters, such as lakes; it is even found in water troughs, cisterns or tanks.	From the Texas border south through Mexico, Central America, and the Caribbean Islands to Colombia and Ecuador, east to Venezuela. It is an avid feeder on both man and animals but while it freely enters houses it does not tarry there long. It is a dangerous vector in part of its range, particularly in Central America, east coast of Mexico and some of the West Indies.
<i>A. aquasalis</i>	In brackish tidal waters either sunlit or shaded. May breed in fresh water such as the rice fields of Trinidad.	Caribbean and Atlantic coasts from Costa Rica to the state of Rio Grande do Sul, Brazil, Trinidad and the Lesser Antilles. Apparently zoophilous and unimportant in much of its range but the principal vector in Granada and coastal Trinidad and of some importance in certain areas of coastal Brazil.
<i>A. bellator</i>	In water collections in arboreal epiphytes (bromeliads) in Trinidad, terrestrial bromeliads in Brazil.	Trinidad and southeastern Brazil. Wild mosquitoes, do not readily enter houses and rarely rest there but attack man viciously in the open. A vector in inland Trinidad and important in southern Brazil.

Table 6-1 (cont.). Some of the more important anopheline vectors of malaria

The most efficient vectors are marked with an asterisk (\*)

Species	Habitat of Aquatic Stages	Distribution and Relationship to Malaria
<i>cruzi</i>	In terrestrial and arboreal bromeliades.	Southern Brazil. Apparently also a wild species but the principal vector in part of its range.
<i>labranchiae</i>	Sunlit brackish coastal marshes and tide waters; inland in various sunlit waters, notably rice fields.	Southern Spain, western Italian littoral, Dalmatian coast, the western Mediterranean coast of Africa, and the highly malarious Mediterranean islands of Sardinia, Sicily, and Corsica. A domestic and anthropophilous species. A very important vector.
<i>l. atroparvus</i>	Prefers sunlit brackish waters but is found in fresh waters, notably the rice fields of Spain and Portugal.	From England across northern Europe to the Baltic, possible range and extension east of the Baltic not clearly established; extends south into Portugal and Spain. A zoophilous species throughout its range. Where abundant in Russia and the rice growing areas of Spain and Portugal, it is an important vector; transmits "winter malaria" in the Netherlands.
<i>A. sacharovi</i>	Sunlit brackish tidal waters or coastal marshes, also in sunlit fresh waters.	North and central Italy, the Balkans, Near East, central Russia east to West China. Feed indiscriminately on man and animals, readily enter houses. A known vector of importance in Italy, the Balkans, and Palestine.
<i>A. superpictus</i>	Associated with mountain or hill streams, in pools, receding streams, in irrigation ditches, and seepages; have even been taken from almost imperceptible water among rocks in receding streams.	Spain, Italy, the Balkans, southern Russia through Asia Minor to southwest India. Anthropophilous and readily enter houses. An important vector in some areas of the Balkans and Iran.
* <i>A. gambiae</i>	Sunlit fresh water both temporary and permanent rain, pools, pits, even hoof prints, ponds, roadside ditches, drains, irrigation furrows, margins of ponds or lakes and, on occasion, in floating mat of larger bodies of water.	Tropical Africa, Madagascar, and the Mascarenes, was introduced into and eradicated from northern Brazil. Anthropophilous but does not consistently go into dwellings, apparently does not tarry there long. A dangerous vector. It has been estimated that three quarters of all the malaria in Africa is transmitted by <i>A. gambiae</i> .
* <i>A. funestus</i>	In permanent streams, particularly backwashes, marshes and temporary pools in river beds.	In much of tropical Africa. An anthropophilous and very domestic species, a dangerous vector, particularly in East Africa from Ethiopia south to Rhodesia.



Table 6-1 (cont.). Some of the more important anopheline vectors of malaria

The most efficient vectors are marked with an asterisk (\*)

Species	Habitat of Aquatic Stages	Distribution and Relationship to Malaria
* <i>A. culicifacies</i>	Sunlit permanent or semipermanent collections of fresh water, irrigation channels, borrow pits, rice fields, and occasionally in brackish water.	Primarily in the plains but extends into the foothills of India, Burma, Ceylon, Thailand and Yunnan Province of China; has been reported from Arabia. A zoophilous species but will feed readily on man in houses, rests in houses or cattle sheds. A weak vector but because of density is one of the world's most important vectors. The principal vector in India, the only known in Ceylon; vector in parts of Burma.
* <i>A. fluviatilis</i>	Sunlit margins of foothill streams, stream pools, and irrigations, sometimes on margins of standing water, viz., lakes, tanks, etc. Rarely below 1,000 ft. elevation; extends to 5,000 ft.; has even been found above 7,000 ft.	Primarily in the Indian area from Baluchistan to Burma; reported also in Turkestan, Thailand, and Tonkin. Apparently an anthropophilous and domestic species but readily feeds on cattle also.
* <i>A. minimus</i>	In grassy margins of slow-moving sunlit streams up to 2,000 ft. elevation; in Shillong up to 5,000 ft. in backwashes and overflow during monsoon, in pools and eddies of larger receding streams during dry season. Can utilize rice fields on occasion.	India (eastern and northern), Ceylon, Burma, Assam, Thailand, Indochina, southern China, and Formosa. Anthropophilous in most of its range and readily enters dwellings. A dangerous vector throughout its range but particularly in the foothills of north India, Burma, and southern China, Assam.
* <i>A. minimus flavirostris</i>	Shaded marginal pools, and eddies of slow-moving foothill streams up to 1,500 to 2,000 ft. elevation; also edges of irrigation ditches, canals and rivers. Never in salt water or in such waters as those in rice fields.	Foothills of the Philippines, Celebes and Java. A wild mosquito which feeds indiscriminately on small animals; will enter dwellings to feed but does not rest there. The only vector in the Philippines but a dangerous one there.
* <i>A. sundaicus</i>	Sunlit brackish or salt water lagoons, swamps or ponds protected by coastal embankments.	India, Burma, Thailand, Malaya, Indochina, Sumatra and Java (Celebes and Borneo). A very strong flier, up to three miles, anthropophilous but will feed readily on animals as well, found in large numbers in human dwellings and cattle sheds. Principal vector in coastal Bengal, Malaya, Indochina, Sumatra and Java.

Table 6-1 (cont.). Some of the more important anopheline vectors of malaria

The most efficient vectors are marked with an asterisk (\*)

Species	Habitat of Aquatic Stages	Distribution and Relationship to Malaria
<i>A. maculatus</i>	Sunlit hill streams and springs feeding such streams up to 4,000 ft. elevation; also found in rice paddies, pools and other standing waters.	Foothills of Asiatic mainland from India to south China and in Formosa, the Philippines and Dutch East Indies. Appears to be zoophilous and thus relatively unimportant in most of its range. Anthropophilous in Malaya, enters houses freely but does not tarry there. The most dangerous vector in the Malayan foothills.
<i>A. umbrosus</i>	In deeply shaded stagnant pools and morasses in the jungle, in deeply shaded brackish waters in the mangrove swamps. Encountered on occasion in more open waters with less intense shade.	Tonkin, Cochin-China, Malaya and Dutch East Indies. A wild species, adults are strong fliers, fierce biters, and usually found in the deep jungle. Apparently zoophilous but readily bites man and will enter dwellings to feed. An important vector when abundant, viz., Malaya.
<i>A. hyrcanus</i> , <i>sinensis</i>	Sunlit quiet waters, such as rice fields, ponds, lakes, swamps, impounded waters, slow streams and stagnant waters, such as canals.	Northeast India, Burma, Indochina, China, Korea, Formosa, and Japan. Apparently readily bites both man and animals, enters dwellings freely and remains there. The most important vector in lowland China and extends into the hills, apparently the only vector in Yangtze Valley of China and in southern Japan.
<i>A. punctulatus</i> complex ( <i>P.p. punctulatus</i> , <i>P.p. farauti</i> )	Sunlit shallow waters, prefer muddy waters such as temporary rain pools, waters in new depressions and excavations either small or fairly large, found nearly as plentiful in fairly clear permanent waters such as stream margins. Found also in brackish water, even in the bilge of small boats. Most abundant near settlements.	Australasian region, viz., Northern Australia, New Guinea, Solomons, New Hebrides and adjacent islands. Feed readily on both man and domesticated animals, enter dwellings to feed but usually do not remain, rest mainly in the dense underbrush. Dangerous vectors throughout their range, particularly when dense.
<i>A. leucosphyrus</i>	In bottom of densely shaded pools, beds of shallow streams, jungle seepages.	India to Malaya, Dutch East Indies. A wild species, but enters houses well after midnight and leaves immediately after feeding. The only vector in Borneo but dangerous there. May be more important than is realized in other areas.



*A. quadrimaculatus* from man, and the development of screening against insect pests in general, appear to have interrupted transmission in the marginal northern communities. Hackett stresses this same sequence of events, with particular stress on the diverting role of increased livestock in the progressive reduction to the point of its elimination in Central Europe by the beginning of World War I, its resurgence with the disrupted economy and reseeded by malaria-carrying veterans, and disappearance again between World War I and World War II; in this area the zoophilic species, *A. maculipennis*, population did not change as much as the domesticated animal population. The mosquitoes were overabundant or not, only in relation to the availability of domesticated animal sources of food. Similarly, it was the subtle influence of human activities, rather than specific control measures, which appeared to have reduced malaria in the marginal areas of Italy and led the Italian malariaologists to speak of "bonification." In Trinidad, the planting of the immortal tree to provide shade for the cocoa trees also provided ideal hosts for the parasite epiphytes, bromeliads, in which *A. bellator* breed, and thus a local malaria problem was created out of growing cocoa. The flooding of lands for rice cultivation has provided excellent and abundant sources of *A. labranchiae* in Portugal, *A. culicifacies* in India, and *A. hyanais sinensis* in China and created malaria problems in those areas. The development of commercial fish culture in Java provided an abundant source of *A. sundaiensis* in the brackish waters of these ponds.

Military operations have not only encountered serious malaria problems but have not infrequently intensified or even created the problem. Thus, troops at advance positions are without benefit of protective netting or screening at night and become the victims of malaria. It was particularly observed in the South Pacific campaigns of World War II that artillery barrage, bombings and, to an even greater extent, the construction of airstrips, roads, and semipermanent quarters, create ideal breeding places in close proximity to troop concentrations. Thus, *A. punctulatus farauti* commonly multiplied many fold over their normal density and were often concentrated close to permanent or semipermanent installations. In some cases such mechanized clearings opened the way for the even more effective vector *A. punctulatus punctulatus* and the malaria problem was created by the necessities of military operations. Even in an attempt to escape malaria the lack of precise information may actually create the problem. Thus, following the Spanish-American War, when the only known vectors of malaria were quiet water breeders, the barracks for troops were built up in the hills away from the "marshlands" and thus in the only malarious part of the islands, since the only vector there is the stream breeding *A. minimus*.

It is not to be assumed that the malaria-carrying mosquitoes and the transmission of the disease is wholly dependent on the organized efforts of man in the support. Malaria exists in tropical Africa and among other native populations where the living requirements are primitive and where man has altered the environment very little. Nevertheless, even in such areas, the direct support of malaria and the intensification of the problem through increasing the density of mosquitoes is much more common than is indicated even by the few examples cited.

**INOCULATION MALARIA.** Although malaria is normally transmitted from man to man by anopheline mosquitoes, it may be transmitted directly by blood inoculation. Thus, malaria has been accidentally transmitted by transfusion with blood from

infected donor (Wright, 1938). Since the favorable reports by von Jauregg in 1922, malaria has been induced by blood inoculation in the treatment of paretics. Experimentally infected mosquitoes from laboratory colonies have also been used to transmit malaria to paretics. However, neither the accidental transmission of malaria in transfusion, or its intentional transmission to paretics, has resulted in any demonstrated outbreak of secondary cases of malaria.

However, extensive outbreaks of severe *P. falciparum* malaria have occurred in both New York City and Cairo, Egypt, from accidental transmission among drug addicts by the use of unclean hypodermic syringes (Most, 1940). Probably other similar, but unreported, outbreaks have occurred.

ENVIRONMENT. From this discussion are excluded those environmental factors which are influenced directly by man, which have been discussed above, but those naturally occurring phenomena which are beyond the control of man are considered.

Climatic factors, particularly temperature, have a marked limiting effect upon the distribution of malaria. While seasonal fluctuations may and do influence the distribution of the several species of malarial parasites, it is the effect of low, or even high, temperatures upon the sporogonous cycle of the malaria parasite within the mosquito which results in limiting the distribution. Many anophelines will survive and thrive at temperatures which will not support growth of the parasite in the mosquito. Stratman-Thomas, in 1940, found that *P. vivax* did not develop in *A. quadrimaculatus* at temperatures below 15° C (59° F) and required 38 days to complete development at this temperature, whereas they complete development in eight days at 30° C (86° F), the maximum temperature at which they would develop. Furthermore, exposure of the mosquito for more than a few days to temperatures less than 10° C (50° F) or more than 18 to 24 hours at 37° C (98° F) prevent subsequent development of the parasites. The temperature alone would limit transmission in temperate zones to the summer season and reduce the amount of that transmission during midsummer. Siddon (1944), working with *A. culicifacies* in India, found that while *P. vivax* would develop at 10° C (50° F), the development of *P. falciparum* only rarely occurred and *P. malariae* never developed at this temperature. Thus, the temperature requirements for the sporogonous cycle in the mosquito alone would sharply limit the geographical distribution of the latter two species.

Most species of mosquitoes require a relatively high atmospheric humidity for survival and development but there is evidence that the parasitized mosquitoes are even less resistant to the drier airs and that the parasites within them have a higher requirement of atmospheric moisture than do the mosquitoes themselves.

BIONOMICS OF THE PARASITE. In addition to the fact that the malaria parasites require mosquitoes for their transmission from man to man and are dependent upon favorable atmospheric conditions for their incubation within the mosquito, there are certain intrinsic factors which, in part at least, govern the biological potential of the several species and strains. To an appreciable degree the process of natural selection has fitted the several strains with the different ecological environments.

Typically (i.e., most of the known strains), *P. vivax* malaria develops a parasitemia with resulting clinical manifestations, during the second or third week after infection from the mosquito bite. Relapses occur within a year but the disease be-



comes quiescent within two to three years. The St. Elizabeth strain has been shown by Coatney and his co-workers to typically relapse 9 to 12 months after the primary attack and this is the pattern usually associated with the overwintering in the subsequent spring relapse of *vivax* malaria in the temperate zone. In the tropics where more or less continuous transmission occurs, both strains with this delayed relapse pattern and those without this delay have survived. Thus, the Madagascar strain characteristically relapses six months or more after the primary attack whereas the Chesson strain (South Pacific) and the McCoy strain (Florida, U.S.A.) more frequently relapse one to three months after the primary attack. Perhaps the best known example of natural selection of strain for a particular ecological environment is that which has occurred in the Netherlands. The strain of *P. vivax* which has persisted is transmitted largely by zoophilous mosquitoes trapped in houses in the fall and has a long incubation period (three to nine months). Thus, the primary parasitemia and primary clinical attack comes the following summer or fall, with continued supply of gametocytes for the mosquitoes remaining in the houses during the second fall and winter. This strain is not prone to relapse.

*P. falciparum* malaria, while a much more fulminating type of disease, usually does not relapse clinically but may relapse parasitologically. However, parasite production in relapse is usually of a low order and of short duration so that it is well adapted for survival in areas with long periods without mosquitoes. Thus, it is basically a tropical infection and less well adapted than *P. vivax* for survival in the temperate zone.

Although *P. malariae* is a highly relapsing species, the total parasite production is low and it requires a much longer time than the other species for development in the mosquito; hence it is a much less ubiquitous species.

*P. ovale* is found commonly only in parts of tropical Africa, although it has been reported elsewhere in the tropics. It is characterized by low parasite production, short period of parasitemia even in the primary attack, and failure to relapse. Thus, it is able to survive only where the optimum conditions for transmission occur.

**Treatment and Control.** There is no evidence that mass treatment has ever eradicated or done more than temporarily suppress attack rates in the treated population. On the contrary, it cannot be asserted that treatment has no influence on the transmission rate in a community. Since the therapeutic agents which have been and are still in use (quinine, quinaquine or atabrine, chloroquine, and paludrine or chlo-guanide) both in individual and mass therapy are not primary gametocidal agents but attack primarily the erythrocytic schizogonous cycle, their obvious effect is to prevent or cure disease by the destruction of these stages in the blood. The sustained use of such drugs as chloroquine or quinaquine (atabrine) for a long period (i.e. year) in the permanent populations in the tropics, or throughout the entire transmission season in the temperate zones, probably reduces transmission during the period of therapy if a significant fraction of the population partakes of the therapy. However, the possibility that gametocytes may be derived, in part at least, from underlying exoerythrocytic schizogony rather than from the erythrocytic schizogony (Lewert, 1950) should not be completely overlooked in considering the role of sustained therapy in the transmission of malaria. Where therapy is systematically administered for a shorter period to those with overt malaria, or even when those with prodromal signs are included, it is questionable whether there are any sig-

ant reductions in the total community supply of gametocytes. The possible effect of the annual consumption of chill tonics containing quinine in home medication in the southern United States before World War II is even more subtle. The hope held in some quarters, perhaps more in desperation than faith, that therapy would prove to be of significant value in the community control of malaria transmission appears to have been abandoned. Nevertheless, continued use of therapeutic agents may have played a role, hardly discernible among the other factors in the epidemiology of the disease in such marginal areas as the southern United States. The role of therapeutic agents in preventing overt malaria will be discussed under control.

In addition to community-wide organized procedures for the prevention and control of malaria, more subtle efforts in community and individual activities have had significant effects. Mention has already been made of bonification, i.e., continued draining for agricultural purposes, the increased raising of cattle in the United States and Europe, and improved housing. To these may be added the increased use of various insecticides by individual householders. Anyone who has worked in the rural areas of the southern United States will be impressed with the amount of such sprays which has been used in the past two decades. With the advent of DDT, the effectiveness of such household spraying must have increased. However, the use of pyrethrum sprays, and even less effective sprays, must have had a significant effect upon malaria transmission. Probably in no other country has spraying by the individual householder been as common a practice as in the United States. It seems likely, also, that such individual efforts would have their greatest effect in an area such as the United States, where transmission by a zoophilous mosquito makes the disease vulnerable to attack.

**Immunity.** Malaria does not elicit a protective immunity comparable to that of smallpox. Thus it has been easy to overlook the probability that immunity plays a powerful role in maintaining various degrees of health in a highly malarious region. In considering immunity, stress may be placed on specific acquired immunity which may or may not play a part in so-called natural immunity and, finally, consideration should be given to the interference of malnutrition upon the development or effectiveness of immunity.

The fact that Negroes are usually quite resistant to *P. vivax* and often suffer less from *P. falciparum* than do whites is commonly ascribed to a natural or nonspecific immunity. There is some evidence in Africa and in Panama that Negro children are susceptible to malaria and that only with continued exposure as they grow older do they develop the protective immunity associated with race. Nevertheless, it is true that adult Negroes with no known previous infection may not develop an overt malaria or even parasitemia upon inoculation with *P. vivax*. However, as Huff points out, there is no indication as to whether or not pre-erythrocytic malaria developed from the inoculum or from previous unknown exposures. Furthermore, Butler and Saper (1947) found that Negro troops exposed to new strains of *P. vivax* in the Pacific area were just as susceptible to infection as whites. It is evident that acquired immunity is at least a factor in the resistance of Negroes to malaria. The recent suggestion that the sickling trait is associated with marked resistance to malaria needs further study.

Most of the critical studies on specific acquired immunity have been conducted with avian and simian malaria. Many of the earlier studies utilized blood inoculations rather than the normal sporozoite infection; this may account for the fact that



the results have often been inconclusive or ambiguous. It is clear, however, that some degree of immunity may persist for months and even years after the last evidence of infection. Thus, in a highly endemic area repeated exposure to infection would provide the stimulus for the maintenance of a highly protective immunity. In tropical Africa such protection of the adult native population has been purchased at the cost of a high infantile morbidity and mortality rate. It has been suggested that any attempt at malaria control, unless it can be developed quickly into complete eradication, might merely increase the amount of malaria in the community by reducing the immunity which is maintained. The argument is not without merit but appears to disregard the fact that such immunity is bought at the price of a high infant morbidity and mortality rate.

In both avian and simian malaria, the serum of the immune animal has both agglutinating and lethal antibodies. Phagocytic cells complete the destruction of the parasites. Thus, the pattern is in keeping with the usual concepts of immunity. However, such immunity is not sufficient to completely overwhelm a new infection except when it is at or near its maximum level; repeated stimuli are apparently necessary to maintain high protection. Furthermore, the immunity is not only largely species specific but, to an appreciable degree, strain specific within a species. Yet even this apparent specificity may be merely quantitative. Boyd and Kitchen have shown that patients recovered from *P. falciparum* infection are partially refractive to new strains of that species. They become infected but suffer comparatively little of the usual pathology. Furthermore, in patients simultaneously inoculated with *P. falciparum* and *P. vivax*, the former will develop and the latter be completely suppressed for some time. Months after recovery from *P. falciparum* malaria, the patient may "relapse" with *P. vivax* malaria. This sequence of events was encountered in military personnel who were unprotected in highly malarious combat areas.

The immunity then is of a comparatively low order and offers complete protection only at its maximum level. Any interference with its development or maintenance will diminish the degree of protection. Apparently, malnutrition is one of the factors which interferes. Relatively little experimental work has been done on the few studies which have been conducted are in accord with similar studies on other parasites (e.g., hookworms and *E. histolytica*) the immunity to which appears to be barely protective. By way of example, Brooke (1945), working with *P. relictum* in pigeons found that a thiamine deficiency interfered with the normal development of immunity to this malarial parasite.

**Malaria Prevention.** Malaria prevention may be conveniently contrasted with control or eradication. Under the heading of prevention may be included such measures as the use of repellents, drug prophylaxis, and the screening of houses. Such measures may be considered as defensive, in an attempt to protect the individual or a selected portion of the population. These may be combined with offensive measures of attack and have their value even today.

Mosquito repellents have their uses among combat troops, hunters, or others who must be abroad at night in malarious areas. Such repellents, however, effective under laboratory conditions, have never been adequately evaluated as the means of preventing malaria in the field. Their use is considered largely in the nature of an emergency measure. They are discussed more fully in Chapter 7.

**Drug Prophylaxis.** None of the therapeutic agents available for routine administration is capable of preventing infection with *P. vivax* and only one of the available drugs is believed to have such effect upon *P. falciparum*. Thus, causal prophylaxis, or true *prophylaxis* is not obtainable against *P. vivax*. However, a number of compounds, quinacrine and the 4-aminoquinolines, will destroy the erythrocytic schizogony as it develops and thus effect *clinical prophylaxis* or suppressive treatment of both *P. falciparum* and *P. vivax*; fewer critical tests have been conducted with *P. malariae* but so far there has been no clear-cut difference between the results with this species and the two more common species. Thus, with all of these drugs, there is little or no interference with the underlying exoerythrocytic schizogony but rather the recurring crops of erythrocytic stages are destroyed in the circulation before overt malaria, or even readily demonstrable parasitemia, can develop. With *P. falciparum* the continuation of the drug prophylaxis for a comparatively short time after known exposure will usually completely prevent the development of malaria. Apparently as little as 10 days' continuance of drugs beyond exposure may suffice to completely prevent the development of *falciparum* malaria but it is generally conceded that a month's treatment beyond exposure will give almost complete assurance of preventing *P. falciparum*. Thus, although technically these drugs are not causal prophylactics, for all practical purposes they serve this purpose in *falciparum* malaria. Therefore, the demonstration that chloroguanide (paludrine) is a true causal prophylactic for *falciparum* malaria does not recommend it above quinacrine or the 4-aminoquinolines.

The results of chemical prophylaxis against *P. vivax* is, however, quite different from that against *P. falciparum*. With the use of chloroguanide as well as with the use of quinacrine and the 4-aminoquinolines overt malaria develops after the termination of the drug prophylaxis. It is postulated that the exoerythrocytic schizogony continues much longer with *P. vivax* than with *P. falciparum* and thus provides the source of the parasitemia. While it is not impossible that the time in which malaria develops after the termination of drug prophylaxis may bear some relationship to the particular drug used, the most conspicuous relationship seems to be to the strain of *P. vivax* involved and the duration of the postexposure treatment. There is even some suggestion that the continuation of drug prophylaxis for 18 months beyond exposure may entirely prevent the development of *vivax* malaria. This is in accord with the evidence that *vivax* malaria frequently runs its full course in less than two years. On a practical basis, however, it may be preferable to continue drug prophylaxis only a month after exposure and thereafter treat those cases which develop rather than attempt the sustained therapy for 18 months or more.

Usually, drug prophylaxis is desired for relatively short periods of exposure but on occasion the procedure may be necessary or desirable for much longer periods. Experience in World War II has shown that quinacrine (atabrine) may be taken effectively and safely for a full year during exposure to infection and reinfection. Clark has recently found that chloroquine and chloroguanide may be taken effectively for a year. Boldt and Goodwine (1949) have continued chloroquine for two years without outward effects and with continued effectiveness. Thus, these compounds offer promise of suppressing malaria where unprotected exposure is required for short, or even protracted periods. However, there is no clear demonstration that the community level of infection can be more than temporarily



depressed. The hope that such drugs could be used to eradicate malaria in a community is still without demonstrated support.

The same drugs which are effective in clinical prophylaxis are also the most satisfactory in effecting clinical cure since in both actions the attack is upon the same stage of the parasite. Since *falciparum* malaria does not commonly relapse, treatment of this infection is for all practical purposes usually curative. However, with *P. vivax* infection relapses occur largely in accordance with the pattern of the particular strain. Relapses should be treated in the same manner as the primary attack.

Since quinacrine, the 4-aminoquinolines, or chloroguanide do not serve either for *causal prophylaxis* or *complete cure* attention has been given to other types of compounds. Attention has been given to the 8-amino quinolines. Of these, primaquine has already proved useful in eliminating *vivax* malaria from United Nations troops returning from Korea. It is not without danger of toxicity, particularly to Negroes. However, it was safely and effectively used in over 300,000 personnel doses of 26.5 mg. primaquine diphosphate (15 mg. base) daily for 14 days (Archambeault, 1954).

The uses and limitations of these several drugs have been reviewed by Coggeshall and Craige, Saper, and Dove in Boyd's *Malariology* (1949) and by Coatney and others (1950a, b), Cooper and others (1950) and Lints and others (1950). Amodiaquin (camoquin) and pyrimethane (daraprim) have been introduced more recently. The latter is markedly gametocidal but is not recommended for continuous suppression of malaria. However, four drugs may be considered for the suppression of malaria. They should be taken throughout the period of exposure and for one month thereafter:

1. Quinacrine (atabrine): 0.1 gm. daily or at least six days a week.
2. Chloroquine (aralen): 0.3 gm. once a week (once every seven days).
3. Amodiaquin (camoquin): 0.3 gm. once a week (once every seven days).
4. Chloroguanide (paludrin): 0.3 gm. once a week (once every seven days).

**Screening of Houses and Use of Bed Nets.** The use of protective screening both the use of bed nets and the screening of living and sleeping quarters, offers effective protection to those who use them nightly. The demonstrations of the effectiveness of screening in preventing malaria in such protected individuals has been so frequently and clearly demonstrated that detailed discussion is unnecessary. It is probable that the increase in the number of screened houses, not necessarily a malaria control measure, in the United States has been a factor in the reduction of malaria in the marginal areas of this country. Many houses in the United States are difficult to screen and it is even more difficult to maintain such screening. In highly malarious areas of the tropics screening of the native dwellings would be almost impossible even if sufficient funds were available. Thus, screening can hardly be considered as a practical measure in any attempt to eradicate or even control malaria on a community wide basis in such areas.

**Control and or Eradication of Malaria.** During the past decade there has been a marked tendency to change our focus of attack upon malaria from *control* to *eradication*. The impetus for this changing objective was the singular success in eliminating from northern Brazil, the potent malaria vector, *Anopheles gambiae*, which had invaded that country from Africa. The rapid recession, under con-

attack, of malaria from the United States and the demonstrated power of DDT in tropical America had added considerable hope that eradication from larger areas is technically possible in the near future. The principal mode of attack at the present time is through the use of residual sprays in homes and gathering places on an organized community basis. That this will suffice in all areas is not evident and certain doubts may be raised. Nevertheless, it is this approach which deserves major emphasis at the present time. It is the only technic which promises widespread control. This is a localized attack upon the mosquitoes which transmit malaria within houses. In most areas of the world this is so nearly the exclusive means of transmission, that what little transmission takes place elsewhere may be disregarded or relegated to the place of a minor secondary problem.

**Residual Spraying.** The attack upon the mosquito in the house was first considered a significant point in control by Prince. Both spraying and swatting the individual mosquito was utilized. This same approach was urged by Swellengrebel in attacking the problem in Holland. With the development of effective space sprays, the attack continued. Park-Ross first demonstrated the value of weekly spraying of the huts with pyrethrum as a malaria control measure in rural India. Russell and Knipe followed this with a more thoroughly controlled study and showed that the weekly spraying of houses during the transmission season, July through December, resulted in almost a 75 per cent reduction in detectable parasitemia of children and nearly a 50 per cent reduction in palpable spleens. However, there was no reduction in the mosquito (*Anopheles culicifacies*) population. The development of the use of DDT as a residual spray opened the way for the more effective attack on that *Anopheles* which came to the houses. Trapido (1946) showed that the application of DDT at roughly four-month intervals to the dwellings in a Panamanian village reduced the malaria rate more than 75 per cent in 14 months. The mosquitoes, *A. albimanus*, were markedly reduced in the houses. Immediately after the first, second, and third applications of spray, 2, 4, and 0 mosquitoes were taken as compared to 87, 40, and 88 in the control villages. Furthermore, there was much less tendency for these mosquitoes to feed; within a four-month period after the application of the spray, 0 to 17 per cent were engorged as compared to 27 to 74 per cent engorgement in the control villages. Thus, malaria transmission was promptly interrupted so that it is likely that some of the parasitemias discovered after 14 months may represent either relapses or infections contracted elsewhere. Furthermore, only 0 to 8 per cent of mosquitoes captured in sprayed dwellings survived for 21 hours as compared with 25 to 50 per cent survival of those captured in unsprayed dwellings. The effect upon the total population of *A. albimanus* was, however, much less impressive. Immediately after spraying there was a reduction in the catches in stables within the village but a gradual recovery in three to six weeks. As little as 300 feet from the village the effect was even less. Thus, while DDT residual prevents malaria transmission there is no evidence that it will eradicate *A. albimanus* and it is questionable whether its continued use for years would see a significantly sustained reduction in their number.

Similarly, Downs and others (1950) have shown that residual spraying in the rice growing towns of Morelos, in Mexico, has all but eliminated *P. falciparum* in five years and has brought the total malaria rate down to barely detectable levels and the vector, *A. pseudopunctipennis*, is rarely found in houses. While there ap-



pears to be some reduction in this mosquito in the immediate village, it is still very prevalent in the area. The mosquito has not been eradicated and some transmission of malaria takes place.

However, the use of residual DDT against *A. darlingi* in British Guiana and in Venezuela has apparently resulted in the elimination of the species in the area treated. Not only was malaria transmission reduced but within two years there was a diminution in both adults and larvae of *A. darlingi*. At the initiation of the work it was planned to apply residual DDT every eight months but by 1948 the interval was lengthened to 10 and 12 months. At latest report, five years after the initiation of the program, no *A. darlingi* larvae or adults can be found within the area covered by residual spray. It is visualized that application of DDT once every 12 months will be sufficient to prevent the resurgence of the mosquito population either from undiscovered foci within the area or infiltration from the periphery.

Similar results are reported by Gabaldon from Venezuela with the same vector.

A totally different picture is given by Smith and Dy (1949) in their attempt to control malaria transmitted by *A. minimus flavirostris* in the Philippines. The application of a residual of DDT every three months produced no discernible reduction in either malaria rates or the density of the mosquito vector. These workers note that this species is a "wild mosquito" and does not deliberately go to human dwellings to feed.

Thus, the effectiveness of residual sprays varies with the habits of the mosquito. Complete eradication of malaria and its vector appears possible by this means alone where transmission is by a highly domestic or anthropophilous species, such as *A. darlingi* of the northern coast of South America, but apparently it offers little or no opportunity to control malaria carried by a wild mosquito such as *A. minimus flavirostris*. It is possible that *A. bellator* of Trinidad and *A. cruzi* of southern Brazil, both "wild species," may not be completely prevented from transmitting malaria by residual sprays alone. Between the two extremes there appear to be ample opportunities for controlling malaria, even eradicating the disease, without actually eliminating the vector. In addition to the examples cited of this type of control in Panama and Mexico, there are reports of similar experiences in India. Singh and Singh (1949), Viswanathan and Rao (1949), and others have reported gratifying reductions in malaria rates following the use of residual sprays of DDT or gammexane (benzene hexachloride) due to the reduction of *A. culicifacies* and *A. fluviatilis* in the dwelling and other sprayed shelters. There is some reason to believe that continuation and extension of the control program may eliminate or markedly reduce the total population of the more domestic *A. fluviatilis* from large areas but there is less hope of so eliminating or reducing *A. culicifacies*. In the United States, the use of residual sprays has undoubtedly added its weight in the final elimination of malaria from this country without materially reducing the vector *A. quadrimaculatus*. The use of residual sprays has resulted in almost complete elimination of malaria from Italy, apparently with significant reduction in anopheline population. It should prove to be a particularly effective weapon against the wild transmitted malaria of Holland.

In Africa, the picture is less clear. There are reports of significant reduction in malaria transmission with or without anopheline reduction (Davidson, 1950). There are other reports indicating the failure of DDT to control either malaria

mosquitoes. *A. gambiae* appears to be the principal focus of uncertainty. Explanations of failures include the suggestion that this species is repelled rather than killed by DDT in low concentration, without interfering with feeding; that transmission takes place outside of the huts as often as within them; and that it is difficult to maintain adequate residual on mud huts. In some cases the possible failure of spray crews to follow directions has been suggested.

Thus, residual spraying offers the single most effective weapon known. In addition to DDT other residuals have been developed; these include benzene hexachloride (Bertram, 1950), lindane, chlordane, and others (see Chapter 7). To an appreciable degree at least it may be anticipated that the improved use of one or another of the residuals may permit more effective attack in such areas as Africa. However, the inevitable conclusion is reached that residual spray alone is not at present the total or final answer to the eradication or even the control of malaria in all areas. Some concern is felt over the possibility that DDT-resistant strains of anophelines may develop to complicate the program, since both flies and culicine mosquitoes have developed such strains in both the laboratory and in nature. Fortunately, so far no such strains of anophelines have developed and their greater susceptibility to DDT lends substance to the hope that such strains will not develop, at least not before malaria transmission has been reduced to the point where other techniques may be effective. Although residual spraying is classified as an attack measure leading to control or even eradication, there is so far no indication that the time may be anticipated even in the United States, British Guiana, or Venezuela, when the control measures can be completely terminated. The wave of malaria a quarter of a century ago in Bombay that resulted from the termination of control measures after the eradication of malaria (Covell, 1928) \* dictates that at least reconnaissance should be maintained.

**LARVAL DESTRUCTION.** When mosquito breeding is in limited, well-defined areas, the drainage of such waters or their control to reduce breeding still is an important part of malaria control. Water fluctuation control in such areas as the C.V.A. reservoir should be considered whenever possible in new impoundments in malarious, or potentially malarious, areas. Water fluctuations in rice cultivation are still effectively utilized in Europe and Asia. Malarial intelligence should be utilized in the clearing of jungles, in the impoundment of waters, and the creation of new concentrations of surface water. The use of larvicides, DDT or others, will still be needed. Larval destruction had largely eliminated malaria from northern Chile before the advent of residual spraying. Similarly, biological adjustment of the brackish water ponds of Java reduced mosquito breeding and eliminated malaria. Larviciding had an important part in eliminating *A. gambiae* from Brazil.

Destruction of the breeding places or the use of larviciding chemicals in the control of malaria transmitted by such wild mosquitoes as *A. bellator*, *A. cruzi*, and *A. minimus flavirostris* is still a possible problem. It may well be necessary to combine such measures with residual spraying in the control of malaria by such means, for example, as *A. albimanus* in Panama and *A. culicifacies* in India. In the attempt to completely eradicate malaria from the island of Sardinia, both larvicides and residual spray has been used against *A. labranchiae*. The cost so far is estimated at not less than \$12,000,000, and it is not yet certain that the goal has been

\* See Covell, in Boyd (1950).



accomplished (Logan, 1950).

CONCLUDING COMMENT. Hundreds of millions of people still suffer from uncontrolled malaria; it still remains one of the major diseases. Technics and weapons for control and eradication in large areas are available. They have been effectively applied in many localities. To what extent they can be adapted to use, and how effective they will be under the varying circumstances, is yet to be ascertained.

Malaria control has become very largely a socio-economic problem.

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## YELLOW FEVER

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Yellow fever is an acute febrile disease characterized by jaundice, albuminuria and a tendency to hemorrhages, especially from the stomach (black vomit). It is due to a filtrable virus, and is spread by mosquitoes. All ages and sexes are susceptible. One attack produces a lifelong immunity. Negroes are as susceptible as whites, although the disease in them is milder and rarely fatal. There are few sequelae. The case fatality rate is ordinarily about 6 per cent, but occasionally it may rise to 60 per cent or higher in closed epidemics. The incubation period is usually two to five days, maximum six days.

The distribution of the disease is shown in Figures 6-1 and 6-2. It is present throughout the great forested areas of South America and Panama, and in a broad belt from 15° N. and 10° S. latitude in Africa. Extensions sometimes occur; between 1950-54 it spread to Trinidad and Central America as far as Northern Honduras.

Transmission by *Aedes aegypti*. The transmission of yellow fever through *Aedes* (*Stegomyia*) *aegypti* was proved by Walter Reed and the U. S. Army's Yellow Fever Commission. It was also shown that the virus was in the circulating blood of the patient only during the first few days of the disease, and that the mosquito which had ingested the virus was not able to transmit it by the bite until





**Fig. 6-1. Distribution of yellow fever in the Western Hemisphere.**

Places known to have had yellow fever cases from 1932 to 1950. (Map prepared by C. G. Inman, Pan-American Sanitary Bureau, by permission of Dr. Fred L. Soper.)



----- BOUNDARY OF YELLOW FEVER ENDEMIC AREA

Fig. 6-2. Distribution of yellow fever in Africa.

Map showing localities in which yellow fever cases occurred from 1921 to 1950. (Prepared by Dr. Henry Kumm.)

After 10 days or more. This is known as the extrinsic incubation period. Once infected, the mosquito remains so for the rest of her life. At first it was thought that man was the only vertebrate host, and that the epidemiologic cycle involved only man and *Aedes aegypti*. Since the patient could infect the mosquito only during a very short period of the active disease, and there were no reservoirs of the virus, it appeared evident that the disease could exist only in localities where there were always active yellow fever cases among nonimmunes supplied by immigration and births, and where *A. aegypti* could exist in large enough numbers to insure contact with the sick. Such conditions were met with only in large centers of population in the tropics, but during the summer months they were also present



in the cities in North America. *A. aegypti* was carried by sailing vessels and after escaping into northern port cities from these vessels, in a short time would build up dense populations during favorable weather. This mosquito is highly domestic and breeds in artificial water containers such as water barrels, clay pots, etc., in which there was an abundance before the installation of modern water and sewerage systems. The disease was introduced by active cases or by infected mosquitoes, and outbreaks occurred as far north as Philadelphia and New York.

The demonstration in Havana and Panama by Gorgas that yellow fever could be eradicated through control of *A. aegypti* was followed by extensive control campaigns in tropical cities, which were considered to be the endemic foci. This resulted in a steady decline of the disease and led to the hope that soon it would be eradicated from the entire world. But newer laboratory techniques, making possible surveys of immunity through the mouse protection test, and the viscerotomy series, which showed the presence of fatal cases through examination of the pathological picture in the liver, revealed the existence of extensive areas of rural endemicity not affected by the control of *A. aegypti*.

**Jungle Yellow Fever in South America.** Soper and his associates (1933) reported the occurrence of rural yellow fever in an area in Brazil where *A. aegypti* was evidently not the vector. Immunity surveys showed that the tree-dwelling monkeys are susceptible to the virus, and captures of wild mosquitoes followed their inoculation into susceptible animals has resulted in the isolation of the virus from several species of forest-dwelling mosquitoes. Laboratory studies proved that a number of mosquito species, including some of those from which the virus was isolated in nature, are capable of transmitting the virus by their bites. Epidemiological studies showed that in South America sporadic cases of yellow fever occur among people whose occupation takes them into the forests. The epidemiological cycle of this *jungle yellow fever* in South America involves the reservoir monkey hosts, which infect the arboreal forest mosquitoes. These monkeys are not a permanent reservoir, as they have only a transient viremia of a few days during which mosquitoes can be infected by feeding upon them. A stable monkey population therefore, soon becomes immune, and mosquito infections die out. The virus passes through the monkey populations in epizootic waves. The mechanism of migration is not well understood; monkeys do not seem to range widely, but there is contact between neighboring populations. Furthermore, the hardy forest mosquitoes, capable of flying from one forest patch to another. The rapid extensions over long distances, and dry-season survival remain unexplained. The mosquitoes which act as vectors of the virus to the monkeys are species of *Haemagogus*, especially *capricorni*, *H. spegazzinii spegazzinii*, and *H. spegazzinii fulco*. Other species may be involved, but their role is not yet understood. The *Haemagogus* mosquitoes have a dark bluish, metallic coloration. The larvae are found in water collected in tree holes in trees and other plant cavities. The adults are arboreal in their habits, feed during the day upon monkeys and other animals living in the trees so that ordinarily people going into the forest are not attacked by the insects in great numbers. However, when the trees are cut down the mosquitoes appear at ground level in numbers and attack the wood cutters; thus, it has been stated that in parts of South America yellow fever is almost an occupational disease. Persons contra-

The infection accidentally in the forest may carry the virus to urban areas where the *man-aegypti*-man cycle may supervene.

**Jungle Yellow Fever in Africa.** In Africa, the arboreal monkeys also serve as so-called reservoirs, and the virus is transmitted to them by *Aedes (Stegomyia) africanus*, which also lives in the forest canopy and feeds upon animals resting in trees (Smithburn and others, 1949). It is interesting to note that during the course of the studies leading to the incrimination of *A. africanus* as a vector, this mosquito could not be captured off monkeys kept in cages in trees, but that it did bite monkeys kept on leashes on open platforms. The former monkeys were protected from yellow fever, while the latter became infected. *A. africanus* bites at night, when the African natives do not enter the forest; thus, there would seldom be an opportunity for the insect to cause an infection in man. However, species of monkeys susceptible to the virus descend from the forest canopy to raid banana plantations near native dwellings. Here they come into contact with *Aedes (Stegomyia) simpsoni*, which is nocturnal about habitations and breeds in plant axils. This mosquito acquires the virus by feeding upon the marauding monkeys, and in turn transmits it to man. A *man-simpsoni*-man or a *man-aegypti*-man cycle may then set in.

**Prevention.** The eradication of classical urban epidemics has been accomplished through control of *Aedes aegypti*. This mosquito is intensely domestic, and so is readily controlled through elimination of tin cans and other unnecessary artificial water containers in and around houses, the periodic emptying of flower bowls, and the like, and the use of fish or insecticides in cisterns and other large water storage tanks. The residual sprays are extremely effective against the adults of this household mosquito. As noted above, at present eradication programs are underway through much of South America. Thus there is little likelihood of the further occurrence of *aegypti*-transmitted urban outbreaks (Theiler, 1948). Control of jungle yellow fever is a more difficult problem. At present neither the reservoir monkeys nor the forest species of *Haemagogus* can be attacked successfully. It appears that the disease will remain a threat, especially to rural populations within the endemic zones, for many years to come.

**Vaccination.** Protection of individuals and whole populations may be obtained through vaccination with attenuated virus. Two strains of the virus are used for this purpose, the French neurotropic and the 17 D strains. The latter was accidentally produced through cultivation of yellow fever virus in tissue culture. The vaccine is produced by inoculation of the virus into chick embryos; after four days' incubation at 37° C the embryos are ground to a pulp, desiccated, and stored in nitrogen-filled ampules. Before use, sterile saline solution is added to the dried material, and 0.5 ml. is injected subcutaneously. Only one injection is necessary. Present evidence indicates that the 17 D vaccine confers immunity for at least six years.

The French method of immunization consists of suspending a vaccine of infected dried mouse brain in a solution of gum arabic and applying this to the scarified skin. Sometimes dried vaccinia virus is mixed with the yellow fever vaccine. This method is discussed in detail by Peltier (1948). In Costa Rica and Nicaragua a number of fatal cases of encephalitis followed the use of the French vaccine, and the Pan American Sanitary Bureau recommends the use of only the 17 D vaccine in the Americas (Yellow Fever Conference, 1955).



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## DENGUE

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Dengue is an acute mosquito-borne fever due to a filtrable virus. The disease is characterized by sudden onset, initial erythema, headache, and pains in the trunk and limbs, especially the joints. The pain and stiffness of the joints causes a characteristic waddling gait; hence, the name dengue. The fever is of short duration and may show a saddleback curve. The pulse is slow, there is a marked leukopenia, a terminal rise, and slow convalescence. The primary rash comes during the first day or two. A secondary rash appears about the fifth day and may be maculopapular or scarlatinous in form. In some epidemics the lymph nodes are involved. Often the disease manifests itself as a mild fever lasting from one to three days, unaccompanied by a rash. Dengue is practically never fatal, but a few deaths have been attributed to it. The pathological picture has been described as including degenerative changes in the liver, kidneys, heart, and brain, and hemorrhages in the endocardium, myocardium, pleura, peritoneum, mucosa of the stomach and intestines, muscles, and central nervous system (Melissinos, 1937).

The virus is in the blood during the febrile stage. This has been demonstrated by injecting volunteers. The incubation period is variable. In experimental infections produced by infected mosquitoes, it ranged from 4 to 10 days, and when produced by injection of blood, 2 to 15 days. Several strains of the virus have been adapted to mice (Sabin, 1948).

An attack is followed by an immunity to that particular strain of the virus which may last for two years and possibly longer. Among the several immunologic types of virus there appears to be at least one common antigen which causes a partial immunity to heterologous strains for periods of two to eight months. Sabin believes that since two or more immunologic types of virus may coexist in a given area, the occurrence of the mild, atypical cases of dengue which are seen during some epidemics may be due to reinfections with heterologous strains. These mild cases are caused by non-infecting mosquitoes.

**Transmission.** The first person to transmit dengue by the bites of mosquitoes was Graham in 1903. He reported transmission with *Culex fatigans*, but as subsequent work showed that the species cannot transmit, Graham must have had

specimens of *Aedes aegypti* among his mosquitoes. Ashburn and Craig in 1907 demonstrated the infective virus in the circulating blood of dengue patients, and reported what appeared to be successful transmission to humans by *C. fatigans*. Ireland and others (1916) transmitted dengue by *A. aegypti*; the ability of this species to act as a vector was further proved by the experiments of Chandler and Rice (1923), Siler and others (1926), and Simmons and others (1931). The dengue patient is infectious to the mosquito 6 to 18 hours before the onset of symptoms and during the first three days of the disease. Mechanical transmission by interrupted feedings of large numbers of mosquitoes is possible, but ordinarily the insect cannot transmit until 8 to 14 days have passed. During this extrinsic incubation period there is a multiplication of the virus until it is possible for transmission to be effected by the bite of the insect. Once infective, a mosquito remains so the rest of her life, provided the temperature does not drop too low. Blanc and Minopetros transmitted the virus with *A. aegypti* 174 days after the mosquitoes had taken their infective blood meal. Simmons and others (1931) showed that a single mosquito could cause the infection.

The above authors also demonstrated that *A. albopictus*, a semidomestic mosquito of the Philippines and other parts of the Orient and closely related to *A. aegypti*, is also a vector. Another *Stegomyia*, *A. scutellaris*, has been suspected on epidemiological evidence for outbreaks in the New Hebrides, and Mackerras has shown this species capable of transmission by the bite. Rosen, Rozeboom, Sweet and Sabin have transmitted the virus by the bites of *A. (S.) polynesiensis*. Koizumi, Yamaguchi, and Tonomura in 1917 reported transmission with *Armigeres obturans*, but the accuracy of this finding has been questioned because the experiments were carried out in an endemic area in Formosa. Negative results were obtained by Sabin and Jahnes with several species of *Aedes* distantly related to the *Stegomyias*, with species of *Anopheles*, and with *Culex pipiens*. The most important vector of dengue is *Aedes aegypti*, while *A. albopictus*, *A. scutellaris* and *A. polynesiensis* may be involved at times.

**Epidemiology.** The epidemiology of dengue, therefore, ordinarily is similar to that of urban yellow fever, involving a man-*aegypti*-man cycle. The disease attacks both sexes and all ages. It is largely confined to cities, showing little tendency to spread to rural areas and villages. It is endemic in the tropics, but extends into the warm subtropic belt and occasionally into temperate regions. All who visit those parts of the tropics or subtropics where *A. aegypti* is still prevalent are likely sooner or later to contract the disease.

Outbreaks of dengue occur with explosive violence and may disable community after community. At Austin, Texas, in 1885, it is estimated that 16,000 out of 22,000 population were attacked; at Cairo, Egypt, in 1880, four fifths of the people are said to have suffered with the disease; in Galveston, Texas, in 1917, it is estimated that one half the population suffered, and in 1922, 60 per cent. Whole army units have been disqualified by the disease.

As there is no hereditary survival of the virus from one generation of mosquitoes to another, it would appear that the disease can maintain itself permanently only in areas where mosquitoes are active throughout the year and where there is a continual supply of susceptible people supplied by births. However, there is some evidence that there may be an extrahuman cycle, similar to that of jungle yellow fever. In-



apparent infections can occur in several species of monkeys, and *A. albopictus* and *A. scutellaris*, which can exist in the bush (and possibly other forest-species *Stegomyia* not yet tested as potential vectors), could act as carriers of the virus from monkey to monkey.

**Control.** The control of dengue epidemics is a counterpart of that of urban yellow fever. It depends upon the control of *Aedes aegypti*, and what has been said about the control of this species also applies to dengue. Where *A. albopictus*, *A. scutellaris* and *A. polynesiensis* are vectors, control measures must include the elimination of these species. Their larvae may be found in tin cans or other artificial water containers about houses, but they are usually found in coconut husks, bamboo stalks, and other small collections of water in plant cavities in coconut groves or bush away from houses. Residual DDT in houses will protect the people from bites by *A. aegypti* and the other *Stegomyias* within houses, but would seem to have little value in preventing infection by the species feeding in the bush. Air spraying by airplanes should be effective against the latter. Sabin suggests that dengue vaccine, produced from virus modified by mouse passage, "may prove to be useful in the control of epidemics and for troops or those who have to move from non-dengue areas into endemic zones." There is no specific drug treatment.

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### MOSQUITO-TRANSMITTED FILARIASIS

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Of the several Filarioidea of man only *Wuchereria bancrofti* and *W. malaya* are transmitted by mosquitoes. The clinical term filariasis is most commonly applied to these infections. They are the species associated with the development of elephantiasis. The more common of the two, *W. bancrofti*, will serve as the basis for discussion. This form is of historical interest, also, since it was with this infection that Manson, in 1879, first demonstrated the mosquito transmission of a disease-causing organism.

**Life Cycle.** The adult worms, both males and females, are found coiled in the lymphatics, usually in the deep lymphatics of the inguinal and pelvic regions. They, with a very thin, shell-like membrane, develop into precociously active embryos in the uterus of the female and are discharged into the lymphatics and make their way to the blood stream still enveloped in the membrane or sheath which has been stretched with the growth of the embryo. These embryos, known as microfilariae,

re 250 to 300  $\mu$  long and scarcely as large in diameter as an erythrocyte; neither the alimentary canal nor the reproductive system is developed in this stage. Once in the circulation, the microfilariae may live for weeks or months, and apparently some as long as a year. In most areas of the world where this infection occurs, the microfilariae show a well-defined nocturnal periodicity in the peripheral circulation. They are most plentiful in the peripheral circulation from about 10 P.M. to 2 A.M. and except in very heavy infections may not be found at all at midday. This nocturnal periodicity may be reversed, sometimes within a week, to a diurnal periodicity by reversing sleeping and active periods of the patients. This appears to have been a factor in the reported reversal of periodicity by therapy.

In a number of Pacific Islands there is a variety or strain of this worm, in which there is no sharply defined periodicity, either nocturnal or diurnal. Furthermore, this form does not appear to develop readily in the species of mosquitoes which is one of the best vectors of the periodic variety. Accordingly, it has been suggested that it is a distinct species.\* However, it seems preferable, until more precise information helps resolve the matter, to distinguish the two as the periodic and non-periodic forms of *W. bancrofti*.

The microfilariae of both forms are incapable of further development unless they are ingested by appropriate species of mosquitoes. In the mosquito, the embryo continues its development, without multiplication, in the thoracic muscles; 10 to 40 days are required for this development. The resulting third stage, or infective larvae, migrate to the head and are ready to enter the proboscis sheath when the mosquito feeds again. Little of the development is known following the entrance of infective larvae into man. Apparently, however, there is some migration, since partially developed forms may be found in the upper extremities in a few months, whereas most of the mature worms appear to become established in the lymphatics draining the lower extremities. Not until about 18 months after infection do the next generation of microfilariae appear in the peripheral circulation. Apparently, the adult worms do not live more than 5 to 10 years.

**The Disease.** Early in the course of the infection, before the worms have matured, various degrees of lymphangitis and lymphadenitis occur. Generalized adenopathy is not common but tends to be restricted to one limb, one leg or one arm: in Samoa, the mumu, as it is called, seems to involve the arms more than the legs. Unilateral funiculitis or epididymitis may occur at this time but often it is not manifest with the first attack of mumu. Later attacks more frequently involve the lower limbs and the genitalia. Subsequent infections and reinfections stimulate the same responses, often with increasing severity as the subject becomes more sensitized. Filarial hydroceles are comparatively common in some areas. The degree of the sensitization is indicated by the fact that skin testing with as little as 0.01 ml. of 1:8,000 dilution of filarial antigen may induce an acute exacerbation of the mumu. No significant permanent damage results from the initial infections nor even from a considerable number of reinfections and superinfection. However, when the subject continues to be exposed to infection for many decades, the increasing inflammation and fibrosis of the lymph nodes, with recurrent edema, results in cellular infiltration of the edemic areas with permanent tissue enlargement. In most endemic areas

\* Ashburn and Craig in 1906 gave the specific name *philippinensis* to the nonperiodic form and Manson-Bahr in 1932 coined the specific name *pacifica* for the same form.



even the beginning of such enlargement is rarely seen before the third or fourth decade of life and conspicuous elephantiasis is seen only in a few of the older subjects. Secondary bacterial infections probably play a part, at least, in some cases both in acute exacerbations of lymphangitis and in lymphadenitis. The fact that it may be impossible to demonstrate microfilariae in the blood of advanced cases of elephantiasis has led to considerable confusion and the suggestion that such conditions are of bacterial origin. Grace and Grace apparently think that streptococcal infections are the essential cause of the elephantiasis. Most workers agree that this interpretation exceeds the available facts. Nevertheless, in Samoa, where *Staphylococcus aureus* was found as the secondary invader in filarial abscesses, penicillin without filaricidal agents frequently relieved the acute episodes promptly. The available evidence indicates that the primary cause of the elephantiasis is recurrent infections with the worm over decades but that secondary bacterial infections may contribute to the ultimate pathology. To discount the role of the filariae as the basic cause of elephantiasis because microfilariae cannot be demonstrated in these advanced cases would be comparable to denying the malarial origin of splenomegaly when malaria parasites cannot be concurrently demonstrated in the blood.

Too much stress has been placed on elephantiasis. This is the end result of the disease in comparatively few individuals. Recurrent attacks of filarial fever or malaria are far more prevalent, at least in the Pacific Islands, and afflict adults of all ages as well as not infrequently adolescents, and children occasionally. These attacks are characterized by fever, often over 102° F, and localized erythema and swelling with marked tenderness in one or more extremity or the scrotum and inguinal lymph nodes. They may last from a day or two to more than a week. Chyluria occurs in all phases of the disease but is more pronounced in advanced cases.

Transients, such as military personnel, have little to fear in terms of ultimate elephantiasis but they may suffer from filarial fever. Among the American Marines on Samoa the fear of elephantiasis and impaired sexual potential among both infected and associated personnel constituted a psychological hazard far greater than the actual medical risk. However, too great emphasis, in the field, on minimizing the dangers could decrease cooperation in prevention and permit an even higher attack rate, thereby increasing the medical problem, the immobilization of personnel in sick bay or hospital, and perhaps increase the chance of permanent damage.

**Geographical Distribution.** Periodic filariasis due to *W. bancrofti* is widely scattered in the tropics. It is, however, rarely found in the highlands. It is common in tropical Africa, southern Asia from India to China and in the islands near the Asiatic Coast from the Philippines to northern Australia and as far east as the Solomons and New Hebrides. It has been introduced into the Western Hemisphere and now constitutes a problem in some of the Caribbean Islands, including Puerto Rico and St. Croix, and in parts of South America, particularly along the Caribbean Coast. It has been introduced elsewhere in this hemisphere but has had difficulty in becoming established in North America. For instance, the only known center in the United States, at Charleston, South Carolina, has apparently completely died out without any concerted or specific attempts at control.

**Transmission.** Throughout its range it is effectively transmitted only by the domestic night biting mosquitoes, *Culex quinquefasciatus* (= *C. fatigans*) appears to be the most important vector throughout most of its range, i.e., the Western Hemisphere.

hemisphere, most of southern Asia and the western Pacific Islands and even in part of Africa. Development has been traced in about 75 other species of mosquitoes but epidemiologically most of them appear to be relatively unimportant. The ubiquitous *Aedes aegypti* may play a part in transmission where it is particularly plentiful but, in general, it appears to be less effective than *C. quinquefasciatus*. The close relative of the latter, *C. pipiens pallens*, appears to be important in part of the Yangtze delta in China. The malaria vectors appear to be important filaria vectors also in some areas, viz., *A. gambiae* in Africa, *A. punctulatus* complex in the Solomons, New Hebrides, New Guinea, and the Celebes, and *A. darlingi* in Brazil and British Guiana.

Nonperiodic filariasis occurs endemically in the south Pacific Islands east of the 170th Meridian, Fiji, Gilbert and Ellice Islands, Samoa, Tokelau, Tonga, and the Marquesas (Tahiti). Throughout this range transmission is by daytime feeding mosquitoes, *Aedes tongae* in Tonga and *A. pseudoscutellaris* throughout the rest of its range. *C. quinquefasciatus*, the most important vector of periodic filariasis, is at least an ancillary vector of the nonperiodic form and there is some evidence that it is refractory (Jachowski and Otto, 1955).

In general, more favorable conditions for transmission are required to maintain endemicity of *W. bancrofti* than to maintain malaria in a community. A greater density of mosquitoes appears to be necessary to produce highly endemic filariasis than to produce a severe malaria problem. Furthermore, filariae appear to be even more susceptible to lower temperatures than is malaria. Thus filariasis has a much more restricted distribution than malaria and is largely confined to limited areas of the tropics.

**Diagnosis.** In endemic areas diagnosis is largely clinical. The characteristic filarial fever or the terminal elephantiasis leaves little room for doubt. Microfilariae may be detected in the blood of most of those suffering the recurring attacks of filarial fever but they are detectable in only a small portion of those with advanced elephantiasis. Furthermore, since the early attacks of filarial fever may occur before the worms have completed development, it is impossible to find microfilariae on such occasions. Nevertheless, it is desirable to check the blood of microfilaria. The amount of filariasis in a community is best determined by blood examinations.

In areas where periodic filariasis occurs blood should be collected at night for examinations; for nonperiodic filariasis the time of examination is relatively unimportant but there may be some advantage in examining daytime blood. The fresh unclotted drop of blood may be examined directly to detect the active wiggling microfilariae. When fresh examination is not feasible, thick smears, as in malaria, are most commonly used. A concentration technic is also valuable when feasible. Knott's technic is best known. Freshly drawn venous blood is diluted in 10 volumes of 2 per cent formalin and allowed to stand overnight. The sediment is examined for microfilariae either unstained or stained with Loeffler's methylene blue. More rapid lysis of blood is obtained with equal volumes of 2 per cent saponin and the microfilariae which remain alive and active are more easily detected (Harris and Summers, 1945).

Intradermal tests, using antigen made from the dog filaria (*Dirofilaria immitis*), may reveal evidence of infection when microfilariae cannot be detected. Such tests may cause an acute exacerbation of filaria fever. Most workers report a high degree of specificity but cross reactions with intestinal worms have been reported.



**Prevention and Control of Periodic Filariasis.** Since this variety is transmitted by night-biting mosquitoes, infection may be prevented by remaining within screened quarters at night and particularly sleeping behind screens or under a bed net. Spraying such quarters to destroy any mosquitoes which penetrate the barriers should contribute to the protection. For this purpose a residual spray is of value but for immediate protection a space spray such as pyrethrum offers distinct advantage. Repellents may also be of value.

The ultimate eradication or even significant control is as yet to be demonstrated. The best results so far have been obtained by Brown and Williams (1949) at St. Croix, the Virgin Islands. Four applications of 200 mg. of DDT per square foot every four months resulted in over 50 per cent reduction in the number of mosquitoes (*C. quinquefasciatus*) collected in the houses and about 75 per cent reduction in the percentage of mosquitoes infected with any stage of the parasite. What is most significant is that none of the mosquitoes after this period contained parasites which had developed to the infective stage. Thus, transmission appears to have been interrupted. There is also some further evidence that transmission had been interrupted, since fewer young children were microfilariae-positive two years after initiation of spraying than were the same age groups before spraying.

In British Guiana, however, Giglioli (1948) found that the application of DDT at intervals of six months or more, which eliminated malaria and its principal vector (*A. darlingi*), had relatively little effect on the principal vector of filariasis, *C. quinquefasciatus*.

It may be that the more frequent application of DDT used by Brown and Williams would result in even more effective control if continued for many years. Since the developmental period of the parasite in man is about 18 months and the developed parasite discharges microfilariae into the blood for years, the actual value of such a program cannot be determined with certainty for years. It is at once evident that residual spraying has considerable promise but that heavier and more frequent applications will be required to destroy these mosquitoes than the similarly domestic anophelines. Not only are the culicine mosquitoes, in general, less susceptible to DDT than are the anophelines but some species of the former have developed resistant strains. To what degree this might complicate long-term use of DDT against *C. quinquefasciatus* is as yet unknown. Thus, residual spraying offers some hope for the control of this infection but the attack on the larval stages cannot yet be abandoned as a major control procedure.

*C. quinquefasciatus* utilizes a wide variety of shaded and partially shaded fresh water. It is a very domestic mosquito and like *Aedes aegypti* readily uses such artificial and domestic waters as those in cisterns, tanks, tin cans, old tires, defective eaves, and a variety of such waters, as well as natural water collections. As in yellow fever control, screening wells and cisterns and the elimination of unnecessary collections of water in artificial containers will eliminate the problem in urban areas and may be significant in many suburban and rural areas.

**Prevention and Control of Nonperiodic Filariasis.** Nonperiodic filariasis is transmitted primarily by mosquitoes which feed in the bush during the day. While they do enter houses, this is common only when the houses are within or adjacent to the bush; they do not tarry in the house and apparently never rest there. Aquatic stages are usually found in small collections of water in tree holes, co-

hells, fallen banana leaves and even artificial containers, such as old cans or bottles in the underbrush. Residual spraying or even screening, except when the house is close to the bush, offers little promise of control. Aerial spraying with DDT has promptly reduced the adult mosquito population in Samoa but had little or no effect upon the aquatic stages so that the adult population was restored to prespraying densities within two weeks. However, since it requires nearly two weeks for the microfilariae to develop to the infective stage in the mosquito, transmission was interrupted. Repetitions of such spraying at approximately two-week intervals over a six-month period produced significant reductions in the mosquito population. Thus, such spraying is of distinct military value but its possible practical value in terms of benefits to the indigenous population is still unknown.

At the present time, the only technic which offers significant protection is the clearing of the bush and destruction of likely water containers by burning or burying. Clearing the bush around habitations is significant because it destroys the harborage of the adult mosquitoes and reveals possible water containers which might otherwise be overlooked. To these may be added the destruction of tree holes by draining, felling, or elimination of the trees. These technics have protected civilian and military personnel living under urban or semiurban conditions. The program is being extended to native villages in several of the Pacific Islands. This does not protect either the native or the immigrant, civilian or military, whose activities take him into the uncleared areas during the daytime.

**Therapy.** In view of the difficulties in mosquito destruction, consideration has been given to the possible value of therapeutic means of destroying the microfilariae reservoir in the indigenous populations, both for periodic and nonperiodic filariasis. Hetrazan will quickly destroy the microfilariae but, to provide freedom from the circulating microfilariae for even six months to a year, the drug must be taken daily for two to four weeks. Field studies have shown that this is possible in limited populations but there has been no demonstration that this has provided any long-term reduction in transmission rates. Certainly, it would require follow-up observations for many years to adequately evaluate such a procedure. Repeated treatments would probably be required at intervals of less than a year to effect significant reduction in transmission. Similar experiences with malaria are not encouraging. However, the difficulties in mosquito destruction and the likelihood that the threshold of transmission is at a higher mosquito density than is the case with malaria in many areas, leads to a recurring consideration of such therapy as at least an adjunctive measure. It is, however, still a theoretical consideration.

Two therapeutic agents have been introduced since World War II, hetrazan and arsenamide (Kenney and Hewitt, 1949; Otto and others, 1953; Hawking and others, 1950). Only the former may be given by mouth and thus is the only one available for mass therapy. Its action on the adult worm is slow and uncertain. At least 2 mg./kg. t.i.d. for 30 days are required to give any assurance of successful destruction of adult worms. Arsenamide can be given only intravenously but 1 mg./kg. daily for 15 days appears to destroy the adult worms.

Individual treatment includes surgical repair of hydroceles and the removal of the elephantoid tissue of the scrotum. Surgical repair of elephantoid limbs is less successful but compression bandages may give some relief here. Penicillin may promptly relieve attacks of filarial fever but there is no evidence that it will cure the



basic condition. Bacterial abscesses may develop during attacks of filarial fever as a result of filaricidal therapy. These may require lancing, treatment with penicillin, or both.

**WUCHERERIA MALAYI.** Biologically, this infection is not materially different from the periodic form of *W. bancrofti*. Earlier suggestions that this infection produced elephantiasis of the upper extremities more commonly than in the lower extremities appear to have been completely denied. Thus, pathologically and clinically the disease, sometimes called Brug's filariasis, is similar to that produced by *W. bancrofti*. The infection has a more limited and even more spotted distribution and is transmitted by mosquitoes of the genus *Mansonia* (*Taeniorhynchus*) (*M. annulifera*, *M. longipalpis*, *M. indicans*, and *M. indiana*), although both *Anopheles hyrcanus sinensis*, and *Aedes aegypti* are reported to be capable of transmitting it. This is the principal filarioidea in Malaya; west of there it is reported from local areas of Assam, northern India and south into Ceylon. North and east of Malaya it is reported from Indochina, south China, Sumatra, Java, Borneo, Celebes, and New Guinea. The *Mansonia* are reported to be night-biting anthropophilous mosquitoes which freely enter human habitations. They should, therefore, be susceptible to residual sprays. The larval stages are attached to submerged vegetation and in North Travancore (India) Sweet and Pilai report control of *annulifera* by repeated hand picking of the water plant, of the genus *Pistia*, to which the larval stages are attached.

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#### ONCHOCERCIASIS

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Onchocerciasis is characterized by conspicuous subcutaneous nodules on parts of the body in which the bones lie close to the surface. Thus, they are commonly seen on the head, parts of the shoulder and pelvic girdles, over the ribs and the knee and elbow joints. The nodules are the end result of the inflammatory response around the adult Filarioidea, *Onchocerca volvulus*, which are ultimately killed within the thick fibrous capsule. These nodules range in size from barely palpable to as large as a walnut. The microfilariae apparently hatch in utero and escape as naked, unsheathed, precocious embryos. They quickly leave the nodule

ut usually do not migrate far and can easily be detected in skin biopsies in the vicinity of the nodules. Nodules on the face are particularly dangerous since the microfilariae from these commonly find their way to the eyes, resulting in transient or permanent blindness. The microfilariae may find their way to the lymphatics and have been reported in the viscera but do not enter the blood stream. It has been suggested that those microfilariae which appear to have migrated more than usual result from unencapsulated adult worms but this has not been demonstrated. It is evident, however, that some worms do develop without obvious evidence of encapsulation since microfilariae may be discovered in the skin of individuals with no discernible nodules. In 1950, C. K. Becker reported finding such worms in three cases in Africa, one while doing a caesarean section, others in repairing two hernias.

**Geographical Distribution.** Onchocerciasis has a very limited and spotty distribution in the African and American tropics. In Africa, the disease is largely confined to central and west Africa from Sierra Leone and French Sudan around the Gulf of Guinea to French Equatorial Africa and the Belgian Congo; and east across the continent to the Anglo-Egyptian Sudan, Uganda, the western part of Kenya, Tanganyika, and Nyasaland. As high as 90 to 95 per cent infection, with detectable nodules, has been reported from some communities in the Belgian Congo, French Equatorial Africa, and adjacent territories.

In the Western Hemisphere, the disease is largely confined to the Pacific slope of Guatemala and southern Mexico (Chiapas and Oaxaca). In these areas, it is confined to elevations between 2,000 and 4,500 feet (Strong and others, 1934). Within this limited locality, however, 30 to 100 per cent of the workers in coffee plantations are said to be infected.

Recently, the infection has been reported in eastern Venezuela (Potenza and others, 1951). This is of particular interest because very few persons have nodules but the skin biopsies are reported by Gonzales and others (1950) to have revealed about 25 per cent infection rates in some communities. Apparently, the disease has remained undiscovered so long because of the absence of nodules.

**Transmission.** The life cycle of this worm is essentially the same as that of *L. bancrofti* except that black flies (Simuliidae) rather than mosquitoes serve as intermediate hosts. *Simulium damnosum* and *S. neavei* are the African vectors and *S. ochraceum*, *S. metallicum* (*S. avidum*), and *S. callidum* (*S. mooseri*) are the common vectors in Guatemala and Mexico. Vargas and Reyes (1949) found that *S. exiguum* is also a potential vector in Mexico. *S. metallicum* is believed, on epidemiological grounds, to be the principal vector in Venezuela.

The larvae and pupae of these flies are found attached to stones or submerged vegetation in stream beds, particularly where shallow water becomes well aerated by tumbling over rocks. The adults are strong fliers and feed readily in the daytime but may feed, to a lesser extent, at night. They attack humans viciously in the open but usually do not enter houses.

**The Disease.** The tumors are benign and only rarely is there secondary bacterial invasion or suppuration. They are, of course, disfiguring, can be very inconvenient, and are sometimes very painful, particularly when attached to the fascia covering the bones. The ocular disturbances are the most significant. Such disturbances, leading to impaired vision or complete blindness, are caused by microfilariae which have migrated from nodules on the head or face. The microfilariae may enter and even



be plentiful in the aqueous humor and can often be readily seen with the slit lamp. This condition is particularly common in Guatemala and Mexico where the nodules are found principally on the head. It occurs also in Africa but is much less common since the nodules there are more frequently on the body or extremities.

**Prevention, Control and Treatment.** The wearing of clothing and head nets, fly areas will offer protection. Repellents may also serve this purpose. Neither, however, appears to offer significant community control. Since the flies rarely enter houses, spraying the house has little or no value against this disease. The attempts to spray vegetation, although theoretically of value, have not had any demonstrable effect. Destruction of aquatic stages of the flies in the streams has been difficult but Garnham and McMahon (1947) have succeeded in eliminating *S. neavei* from a valley near Nairobi in Kenya by the use of a constant drip of DDT upstream from the breeding sites. Similar use of DDT and gammexane (benzene hexachloride) is said to hold promise in Mexico.

Treatment as a means of reducing the microfilaria reservoir has been considered but there is no evidence so far that it has any significant value. In the treatment of the individual, Burch recommends Bayer 205 (Suramin). Hetrazan by mouth quickly destroy the microfilariae and produce a severe allergic reaction followed by improvement in the ocular manifestations. Hawking and Laurie (1949) report that the adult worms are not killed by Hetrazan; thus, improvement appears to be only temporary. The possible dangers of massive destruction of microfilariae in the eye by this or any drug have not been fully explored. Surgical removal of the nodules is effective.

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#### OTHER FILARIOIDEA

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Of the other Filarioidea, *Mansonella ozzardi*, *Acanthocheiloneima perstans*, *A. streptocerca*, may be dismissed without discussion since they are not associated with any clear evidence of disease. Brief mention may be made of *Loa loa*.

Loiasis occurs endemically only in limited areas of central and north Africa. Infection rates as high as 15 per cent have been established by the examination of a single blood smear in the south part of the Anglo-Egyptian Sudan. It is common in parts of the Belgian Congo and French Equatorial Africa; it has roughly the same geographical distribution as *Onchocerciasis* in Africa, except that it does not extend as far south of the equator as the latter. It appears to be the common

larioid infection contracted by missionaries and other white immigrants in Africa.

The adult worms live a free and migratory life in the subcutaneous tissues and on occasion migrate beneath the bulbar conjunctiva and even into the superficial layers of the cornea. The microfilariae are sheathed and must be distinguished from those of *W. bancrofti*. They are found in the circulating blood both night and day but they have a definite diurnal periodicity, being somewhat more plentiful at noon than at any other time. Transmission is by the tabanid flies, *Chrysops dimidiata*, *C. placea*, and perhaps *C. distinctipennis*. These flies feed in the daytime and attack man in the open but do not enter houses.

Although the adult worms may often be easily seen as they raise the skin on moving, no pain or swelling is evident at these locations. Even their presence in the eye is often without material disturbance beyond the shadows they cast in the visual field. However, transient but recurring swellings, commonly known as Calabar swellings, are characteristic of the disease. These are apparently of allergic origin and there is some suggestion that desensitization takes place after decades of infection in the native population. Calabar swellings are particularly common in infected Europeans and Americans. The swellings result from subcutaneous edema; they are nonpitting and rarely inflamed. They may occur on any area of the body but are characteristically seen on the ventral surface of the wrists and the palms of the hands. They are frequently seen on the ankles also. The swollen eyelids are more conspicuous but less common. There is no tendency for the swellings to be localized in the vicinity of the adult worm. Eosinophilia of 20 to 40 per cent is common.

**Prevention and Treatment.** The only prevention is protection from the bites of flies by use of protective clothing or insect repellents. Such measures are difficult to maintain constantly. No community-wide control programs have been developed.

When the worms are readily detected they may be surgically removed. Hetrazan, which has been tried against a number of filarioids, is perhaps the most effective against this worm. It appears to be the drug of choice; Shookhoff and Dwork (1949) found that as little as 0.1 gm., t.i.d., for 10 days was effective in some cases but in others the treatment might have to be repeated. This is less than the 2.0 mg./kg. used as the individual dose in other filarioid infections. Since the drug itself is relatively nontoxic, it may be preferable to raise the dose to 2 mg./kg., t.i.d., for 5 days.

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### THE ARTHROPOD-BORNE VIRUS ENCEPHALITIDES

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During the past two decades much information has been assembled concerning a group of disease processes which have caused epidemics of encephalitis in man. Hammon (1948) suggested that the term "arthropod-borne virus encephalitides" would be an appropriate name to apply to this rapidly growing collection of pathological entities. Insofar as is known at present, all of them are transmitted in nature either by insects or acari and all of them are caused by filtrable viruses.



They include four diseases encountered in the Western Hemisphere, two from the Orient and one from Africa. Among the former, eastern, western and Venezuelan equine encephalitis should be mentioned as well as St. Louis encephalitis. The oriental maladies comprise Japanese B and Russian (Far Eastern) tick-borne encephalitis. The most recent addition is West Nile encephalitis, which was discovered in 1937 by Smithburn and his associates in Uganda, East Africa. There are indications also that louping-ill of sheep may belong in the same group.

In man, these diseases are characterized by a sudden onset with headache, fever, chills, nausea, vomiting, generalized pains and malaise. Within a day or two marked drowsiness or stupor supervenes and a stiff neck often becomes a prominent symptom. Mental confusion, speech difficulties, tremors, convulsions and coma may develop in severe cases. A moderate degree of leukocytosis as well as pleocytosis are common laboratory findings.

In this group of diseases man is usually only an accidental host in a natural process, which functions in the complete absence of human beings. Incubation periods vary from 5 to 21 days. Japanese B and eastern equine encephalitis result in a high proportion of severe and fatal cases, while western equine and St. Louis encephalitis are more benign illnesses, at least in man.

For purposes of clarity, the etiology, distribution and epidemiology of the seven disease entities will be considered individually.

#### ST. LOUIS ENCEPHALITIS

Between July and November, 1933, approximately 1,100 cases of encephalitis were registered in the city and county of St. Louis, Missouri. In this epidemic there was no particular race or sex prevalence and multiple cases in the same family were rare. The incidence of cases in the county in proportion to population was thirteen times as great as in the city. Fatality rates approached 20 per cent.

The virus nature of this disease was soon discovered by two independent groups of investigators. Mice proved to be more susceptible than rhesus monkeys to intracerebral inoculation. Pathological changes consisting of a meningo-encephalitis were more evident in the cerebral cortex than in the basal ganglia or midbrain.

Reeves (1948) states that outbreaks of, or immunity to, St. Louis encephalitis have been encountered in the states of Arizona, California, Missouri, New Mexico and Texas, as well as in the Belgian Congo and Kenya Colony. Mixed epidemics of St. Louis and western equine encephalitis are common in the western United States. Both viruses were isolated from wild mosquitoes caught in the Yakima Valley of the State of Washington.

In order to confirm the diagnosis in a human case it is necessary either to isolate the virus or to make serological tests of paired specimens of sera collected in the acute and convalescent stages of the disease. If antibodies against St. Louis virus are absent from the first specimen and present in the second, it may be concluded that the patient has had St. Louis encephalitis. With regard to the isolation and identification of the virus it should be pointed out that the active agent has not been recovered from the spinal fluid of human beings and only rarely from the blood. If the patient dies, the virus may be recovered from brain or spinal cord tissues.

It was early suspected that mosquitoes might be responsible for transmission and this supposition was shown to be correct when Hammon and Reeves (1934) found naturally infected specimens of *Culex tarsalis*, *Culex pipiens* and *Aedes*

*orsalis*. The species of arthropods which have been found infected in nature with the seven types of encephalitis included in this discussion are listed in Table 6-2.

Table 6-2. Species of arthropods found naturally infected with encephalitis viruses

### A. MOSQUITOES

Species of Mosquito	Type of Encephalitis						
	St. Louis	Western Equine	Eastern Equine	Venezuelan Equine	Japanese B	Russian Tick-borne	West Nile
<i>Culiseta dorsalis</i>	x (3)	x (3)					
<i>Anopheles freeborni</i>		x (3)					
<i>Culex antennatus</i>							x (16)
<i>Culex pipiens pallens</i>					x (8)		
<i>Culex pipiens pipiens</i>	x (3)	x (3)					x (16)
<i>Culex restuans</i>		x (9)					
<i>Culex stigmatosoma</i>		x (3)					
<i>Culex tarsalis</i>	x (3)	x (3)					
<i>Culex tritaeniorhynchus</i>					x (4)		
<i>Culiseta inornata</i>		x (3)					
<i>Culiseta melanura</i>			x (1)				
<i>Culex tritaeniorhynchus perturbans</i>			x (6)				
<i>Culex tritaeniorhynchus titillans</i>				x (2)			

### B. OTHER ARTHROPODS

Species of Arthropod	Type of Encephalitis						
	St. Louis	Western Equine	Eastern Equine	Venezuelan Equine	Japanese B	Russian Tick-borne	West Nile
<i>Dermanyssus americanus</i>		x (15)					
<i>Dermanyssus gallinae</i>	x (12)	x (13)	x (5)				
<i>Omenacanthus stramineus</i>			x (5)				
<i>Codex persulcatus</i>						x (11)	
<i>Hipponyssus bursa</i>		x (14)					
<i>Hipponyssus sylviarum</i>		x (10)					
<i>Triatoma sanguisuga</i>		x (7)					

1. Chamberlain, Rubin, Kissling and Eidson (1951).
2. Gilyard (1944).
3. Hammon and Reeves (1945).
4. Hammon, Tigertt, Sather and Schenker (1949).
5. Howitt, Dodge, Bishop and Gorrie (1948).
6. Howitt, Dodge, Bishop and Gorrie (1949).
7. Kitselman and Grundmann (1940).
8. Mitamura, Kitaoka, Watanabe, Hosoi, Tengin, Seki, Nagahata, Jo and Shimizu (1939).
9. Norris (1946).
10. Reeves, Hammon, Furman, McClure and Brookman (1947).
11. Silber and Soloviev (1946).
12. Smith, Blattner and Heys (1944).
13. Sulkin (1945).
14. Sulkin and Izumi (1947).
15. Miles, Howitt, Gorrie and Cockburn (1951).
16. Taylor and Hurlbut (1953).

The seasonal incidence of St. Louis encephalitis is characteristic, most cases occurring in the late summer and early fall. This observation led Hammon and Reeves (1943) and numerous other investigators to make studies of the potentialities of many kinds of mosquitoes as vectors of the virus. Fifteen species have been shown



experimentally to be capable of transmitting St. Louis encephalitis by bite to suitable animals.

Up to the present time, however, only two species of *Culex* and one of *Aedes* have actually been incriminated under natural conditions. As a source of virus for infecting mosquitoes, chickens are superior to mammals, though chickens do not become chronic carriers. In the Yakima Valley, Hammon made numerous precipitin tests with *Culex tarsalis* and he found that about half of those tested had fed on birds. *C. pipiens* also preferred bird blood though *A. dorsalis* fed more readily on horses.

As transovarian passage of the virus does not occur in any species of mosquito, an explanation is needed of how the disease survives the winter season. No virus was isolated from more than 5,000 hibernating specimens of *C. pipiens* and *C. tarsalis* tested in Washington. Blattner and Heys (1944) have secured experimental transmission with the American dog tick, *Dermacentor variabilis*, but there has been no evidence suggesting that ticks are actually implicated in nature.

A more promising line of investigation appears to be that of Smith and others (1944), who isolated St. Louis encephalitis virus from chicken mites, *Dermanyssus gallinae*, during a nonepidemic period in St. Louis. Neutralizing antibodies found in young chickens living in an area where human beings were not developing the disease, suggested that some blood-sucking vector, which did not bite man, was transmitting the virus among fowls. In 1948, these same workers were able to show that chickens bitten by infected *D. gallinae* circulate virus in sufficient concentration to infect other mites or mosquitoes, and that the latter could transmit the infection by bite to normal chickens or to hamsters. Transovarian passage of virus readily occurs among chicken mites. In the St. Louis area, therefore, the survival of the virus during the winter season is readily explained.

However, Hammon and Reeves (1946) have suggested that the epidemiology of St. Louis encephalitis in the Pacific Coast states may not be the same as that postulated for the endemic area near St. Louis, since more than 100,000 chicken mites have been examined by them with entirely negative results. They feel that California and Washington wild birds and their parasites may be more important than chickens and chicken mites as reservoirs for St. Louis virus during the winter months.

Both men and horses are accidental hosts. Natural immunity has been observed in a wide variety of mammals, including horses, cows, dogs, sheep, goats, pigs, rats and rabbits. Among birds which have been surveyed, immune chickens, ducks, geese, turkeys, pheasants, quail, pigeons and a burrowing owl have been found. Frequent antibodies against both St. Louis and western equine encephalitis virus have been encountered in the same animal or bird.

#### WESTERN EQUINE ENCEPHALITIS

The symptoms of this disease in horses were described by Large in 1867, but it was not until 1931 that Meyer and his associates proved conclusively that the etiological agent was a virus.

Although this is a widespread and very serious disease among horses, it is by all means confined to equines. Leake (1941) reported that 1,260 human cases occurred in North and South Dakota, 250 in Nebraska, 64 in Montana and 43

Manitoba. Eklund (1946) gave a detailed account of the 1941 outbreak in Minnesota, which involved at least 850 people. Human cases were predominantly rural and most prevalent among adult males. The case fatality rate was 9.7 per cent. Whereas poliomyelitis is essentially a disease of children, western equine encephalitis has a high incidence among the older age groups.

Reeves (1948) states that western equine encephalitis has been found in all of the western states and as far east as Michigan, Texas, and Alabama. It has also been observed in Canada and Argentina. This malady is characteristically a summer disease, the enormous Minnesota outbreak having taken place between June 21 and September 18, with a peak of reported cases early in August.

Many laboratory transmission experiments have been carried out, a dozen species of mosquitoes having been incriminated by bite.

Seven, as shown in Table 6-2, have been found infected under natural conditions, the most important being *Culex tarsalis*. Hammon and Reeves (1945) isolated the virus of western equine encephalomyelitis 75 times from *C. tarsalis* caught in the Yakima Valley, Washington, in California and in eastern Nebraska. In addition, they isolated virus twice from *Aedes dorsalis* and once each from *Anopheles freeborni*, *Culex pipiens*, *Culex stigmatosoma* and *Culiseta inornata*. The following year Norris (1946) found naturally infected specimens of *Culex estuans* near Winnipeg, Manitoba.

An unusual finding was that reported by Kitselman and Grundmann (1940) who succeeded in demonstrating the presence of western equine encephalitis virus in three out of five lots of *Triatoma sanguisuga* taken near Garrison, Kansas. Two horses pastured in the same field, where the infected cone-nosed bugs were captured, had died previously of encephalitis. *T. sanguisuga* normally live in the burrows of wild rodents and feed readily on horses. It has not yet been possible to decide whether triatomines actually play a significant role in the transmission of the disease or whether those infected bugs were merely examples of "dead-end infections."

Syvertson and Berry (1941) have shown that the wood tick, *Dermacentor andersoni*, can be infected experimentally with western equine encephalitis virus and that ticks can transmit the disease by bite to ground squirrels, *Citellus richardsonii*. Transovarian passage of the virus also occurs in this species of tick, but the actual role of ticks in nature, if any, has not yet been ascertained.

Sulkin (1945) isolated encephalitis virus of the western strain from *Dermanyssus gallinae* caught in Texas and two years later Sulkin and Izumi (1947) found naturally infected specimens of *Liponyssus bursa* in the same area. Meanwhile, in Kern County, California, Reeves and others (1947) had recovered western equine encephalitis virus from wild bird mites, *Liponyssus sylviarum* captured in the recently deserted nest of a yellow-headed blackbird. Similarly in Weld County, Colorado, Miles and others (1951) found virus in *Dermanyssus americanus* taken from the nest of an English sparrow. It appears, therefore, that whereas chicken mites have been incriminated in Texas, wild bird mites may be more important than chicken mites in California, Colorado and Washington.

Further studies of wild bird mites in California led, in 1948, to a remarkable finding which was reported by Hammon and his associates. From a collection of *Liponyssus sylviarum* they isolated a strain of virus which appeared to be either



a mixture of both St. Louis and western equine encephalitis viruses or else a "ste virus" from which those two agents had originally evolved. A final decision on the exact status of that new strain of virus has not yet been made.

Hammon and Reeves (1946) observed that chickens infected with western equine encephalitis by the bite of *Culex tarsalis* showed no sign of illness, but the circulated virus for a few days in a titer sufficiently high to infect other mosquitoes. This temporary viremia in chickens was followed by a firm immunity. Horses which had been infected by mosquito bite did not circulate enough virus to infect normal mosquitoes. The basic cycle, therefore, was one involving birds and mosquitoes while men and horses were merely accidental hosts. The true reservoirs appear to be various species of bird mites.

An investigation into the bionomics of *C. tarsalis* in relation to western equine encephalitis was carried out by Jenkins (1950). He reported that *C. tarsalis* was very common west of the Mississippi River from Canada to Mexico, its distribution being quite similar to that of western equine encephalitis in horses. That species of mosquito attained its maximum abundance between July and September, the preferred hosts being wild and domestic animals and birds but not man. *C. tarsalis* fed readily at dusk or at night and had a flight range of up to two and a half miles. Some of the adults mate in the fall and females can overwinter in protected places. *C. tarsalis* were unusually abundant in the summer of 1941 when a severe epizootic of equine encephalitis swept across the northwestern states.

In addition to horses the virus of western equine encephalitis has been isolated from a prairie chicken, red winged blackbirds, a magpie and a deer. Neutralizing antibodies have been found in horses, mules, cattle, pigs, sheep, goats, dogs, rabbits, mice, a weasel and a chipmunk. Among the birds, natural immunity has been encountered in chickens, ducks, geese, turkeys, pheasants, partridges, quail, pigeons, doves, woodpeckers, robins and the burrowing owl.

Formolized vaccines of various types have been recommended for immunizing animals. The possibilities of control of the arthropod vectors should be carefully considered, wherever these are known.

### EASTERN EQUINE ENCEPHALITIS

Eastern equine encephalitis was first recognized as a distinct disease entity in 1930. Three years later two different groups of investigators reported the isolation of the causative agent from horses. During an extensive epidemic in eastern Massachusetts in 1938 the virus was also obtained from man. At that time the case fatality rate in horses was about 90 per cent, while 25 out of 38 known human cases died. Children seemed to be particularly vulnerable.

Ten Broeck and others (1935) called attention to serological differences between the viruses of the eastern and western types of equine encephalitis. The seasonal incidence of the two maladies, however, was quite similar, eastern equine encephalitis also being a disease of the late summer, reaching its peak of prevalence in September. Epizootics among horses were studied in New Jersey, Delaware, Maryland, and Virginia, and it was noted that the distribution of equine cases was closely related to the salt marsh areas, infections appearing in contiguous flocks without any actual contact having taken place between the sick animals. It

observations such as these which suggested that the disease might be carried by mosquitoes.

According to Reeves (1948), eastern equine encephalitis has been found in most of the eastern states and as far west as Michigan and Texas. It has also been identified from Argentina, Brazil, Canada, Cuba, Mexico, Panama, and Venezuela.

The incubation period in a horse is about four days and virus may circulate in equines before the onset of fever. This illness is not primarily an infection of horses, but, as in the case of western equine encephalitis, both horses and men serve only as accidental hosts. The true reservoir hosts are various species of domestic and wild birds and their parasites. Chickens and turkeys after superficial inoculation of a small amount of infectious material will show high titers of virus in the blood for several days followed by the appearance of neutralizing antibodies. Eastern equine encephalitis virus has been isolated from sick pheasants, and recovered birds have been found to be solidly immune.

Table 6-2 indicates that two species of mosquitoes have been incriminated in nature. Howitt and others (1949) recovered virus from *Taeniorhynchus perturbans* (*Mansonia perturbans*) captured in Burke and Jenkins Counties, Georgia, during an epizootic of encephalitis among horses. More recently in Louisiana, Chamberlain and his colleagues (1951) obtained infected *Culiseta melanura* near where an infected purple grackle had been shot.

Feemster and Getting (1941) studied the distribution in eastern Massachusetts of six of these potential vectors. They were prevalent throughout the summer months and reached their peak of abundance in September. Feemster and Getting concluded that *A. vexans* was probably the most important of them, at least during the 1938 epidemic in Massachusetts, because it was extremely common and because it was found wherever the disease had occurred.

Howitt and others (1948), working at Shelbyville, Tennessee, isolated the virus of eastern equine encephalitis from chicken mites and chicken lice, *Dermanyssus gallinae* and *Eomenacanthus stramineus*, respectively. Immune horses, cows and chickens were found in this area. This observation suggested the possibility of a fundamental reservoir mechanism in chickens and chicken parasites similar to that which has been postulated for St. Louis encephalitis by Smith and others (1948) as a result of studies carried out near St. Louis itself.

In spite of the severity of the average attack, a certain number of human beings and horses may become immunized with little or no clinical reaction. Birds generally have an asymptomatic viremia, though one epizootic was described among pheasants, which was characterized by a mortality rate of 22 per cent. Formalin-inactivated vaccines prepared from infected chick embryos have been recommended for preventing the disease in animals.

#### VENEZUELAN EQUINE ENCEPHALITIS

Venezuelan equine encephalitis is a serious disease of horses which has been identified from Colombia, Ecuador, Panama, Trinidad, and Venezuela. In human beings it generally causes only a mild illness though two fatal infections were reported in 1943 from the island of Trinidad.

In 1935, an extensive epizootic was studied among horses and mules in



Colombia and three years later the virus was isolated by Beck and Wyckoff in Venezuela and differentiated from other members of this group.

Gilyard (1944) captured naturally infected specimens of *Taeniorhynchus titillans* (*Mansonia titillans*) in Trinidad and he also transmitted the disease to a normal donkey with mosquitoes of this species. In addition, the virus has been transmitted in the laboratory by *Aedes geniculatus*. The reservoirs of this disease in nature are still to be found.

### JAPANESE B ENCEPHALITIS

This name has been used by Japanese workers to distinguish the oriental insect-borne type of encephalitis from Von Economo's disease or encephalitis lethargica. Cases were first observed in 1871 and a very severe epidemic broke out in Japan in 1924. It was not until 1936, however, that the virus was definitely identified by Kasahara, Kawamura, Taniguchi and their co-workers.

In Korea and Okinawa, Japanese B encephalitis has recently posed a serious problem for the occupying troops. Many local children have been infected as well as some of the military personnel. It has also been identified from Guam, the Philippines, China, Formosa, Korea, Malaya, and Siberia. Australian X disease or Murray Valley encephalitis appears to be very closely related to Japanese B encephalitis.

Pathologically, this disease produces a meningo-encephalitis, the structures most severely affected being the thalamus, substantia nigra and the gray matter of the cerebral cortex. Tissue from the central nervous system is the best type of material from which to attempt to isolate the active agent.

Japanese B encephalitis is a summer disease. Males are attacked more frequently than females. Only two species of mosquitoes have so far been found infected in nature. Hammon and others (1949) isolated the virus from a pool of *Culex tritaeniorhynchus* collected in a cow barn in the Okayama prefecture of Japan. They pointed out that the seasonal prevalence and geographical distribution of this species made it highly suspected. No virus was obtained by those workers from *Culex pipiens*. However, Mitamura and others (1939) reported that they had obtained naturally infected specimens of both *C. tritaeniorhynchus* and *C. pipiens pallens* from that same region.

Many laboratory transmission experiments have been carried out both with oriental and with occidental species of mosquitoes. Seventeen species have been found to be capable of transmitting the virus by bite.

Chickens have not been implicated in the epidemiology of this disease in Japan but house finches, following minute inoculations, do circulate virus in amounts sufficiently large to infect mosquitoes. This virus also has been found to circulate in horses, pigs and goats, two strains having been isolated recently from the brain tissue of horses. Sabin and others (1947) reported that natural immunity had been found in horses, cattle, pigs, goats, and rabbits, but not in chickens. They suggested that arthropod vectors other than mosquitoes might serve to maintain the virus during nonepidemic years. Evidences of natural immunity to Murray Valley encephalitis have been found in Australian cormorants, herons, ducks and swans.

Various types of immunizing agents have been prepared, including mouse-brain

and chick-embryo vaccines. The response to initial vaccination is moderate and transitory, though revaccination is said to produce more striking serological changes. The protective value of these vaccines has not yet been determined.

#### RUSSIAN (FAR EASTERN) TICK-BORNE ENCEPHALITIS

Russian (Far Eastern) encephalitis was first observed in 1932 as a springtime disease, which principally attacked persons who were working in the uncleared virgin forests of Siberia. More recently, it has also been reported from European Russia, Austria, Bohemia and Moravia. Silber and his associates isolated the virus in 1937 (Silber and Soloviev, 1946). Mice can be infected by intranasal, intravenous or subcutaneous inoculation but the intracerebral route in mice appears to be the most efficient method.

The clinical picture is not unlike other types of encephalitis except for a residual paralysis of the brachial plexus and muscles of the neck which is said to occur in more than 20 per cent of recovered patients. A drooping head gives these patients a very characteristic appearance. Mortality rates vary from 2 to 15 per cent. Sera collected from convalescent cases within 30 days or more of recovery neutralize the virus.

The annual peak of human cases occurs in May or early June. Men from 20 to 30 years of age are more commonly attacked than women. The patients have usually not been in contact with one another and mosquitoes are not present in those regions at the time of the appearance of the first cases each spring. Secondary cases do not occur in nearby urban areas.

The virus has been isolated from naturally infected ticks of the species *Ixodes persulcatus* and transovarian transmission has been demonstrated. Infected ticks have been obtained after hibernation and before they had fed on any animals in the early spring. Two other species of ticks have been infected in the laboratory, *Dermacentor silvarum* and *Haemaphysalis concinna*.

The etiological agent has been isolated from the brain of several fatal human cases and also at times from the liver, spleen, spinal cord, and blood. Two strains of virus were obtained from wild chipmunks. The Amur hedgehog, *Erinaceus amurensis*, is susceptible experimentally and has once been found infected in nature. That particular infected hedgehog was heavily parasitized by *Ixodes persulcatus*. No final conclusion has been reached concerning the principal animal reservoirs of this disease.

Immunologically, the viruses of Russian tick-borne encephalitis and louping-ill are closely related. Japanese B and St. Louis encephalitis also show a certain degree of group relationship, but western equine encephalitis is quite separate and distinct serologically. Smorodintsev (1956) has prepared a formalin-inactivated vaccine which is said to give some protection against Russian encephalitis.

#### WEST NILE ENCEPHALITIS

West Nile virus was originally isolated by Smithburn and others (1940) from the blood of an African woman with fever who was examined during a survey of the West Nile District of Uganda. This neurotropic agent is related immunologically to the viruses of St. Louis and Japanese B encephalitis. It is pathogenic for monkeys and rodents when inoculated intracerebrally.



Natural immunity to West Nile virus is widespread among the human population of Egypt, the Sudan, Kenya Colony, Uganda and the Belgian Congo. In an endemic area situated in the delta of the Nile, strains of virus were isolated from the blood of two pigeons and a crow.

Two species of mosquitoes, *Culex antennatus* and *Culex pipiens*, are able to transmit the virus by bite under laboratory conditions and the former has on several occasions been found infected in nature. In addition natural infection was demonstrated by Taylor and Hurlbut (1953) in three pools of mosquitoes containing specimens of both *C. pipiens* and *C. univittatus*.

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## AFRICAN TRYPANOSOMIASIS

*(African Sleeping Sickness)*

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African trypanosomiasis is a chronic infectious disease caused by flagellates (Protozoa) of the genus *Trypanosoma*. On the basis of morphology and biology, the many species which have been described from mammals fall into a limited number of more or less distinct groups. The organisms causing African sleeping sickness belong to the *brucei* group which includes three forms, commonly considered as three species, but which are morphologically indistinguishable one from the other:

*T. brucei*: cause of Nagana in equines; also infects cattle, in Africa.

*T. gambiense*: cause of most of the sleeping sickness of man in Africa. Man serves as the only significant reservoir.

*T. rhodesiense*: cause of a more fulminating type of the disease in man. Very spotted in its distribution.

There is not complete agreement on the taxonomic position of these forms but there appears to be growing support for the postulate that *T. brucei* of wild ruminants, and now a common cause of disease in domestic cattle and equines, is the parent form.

Thus, *T. gambiense* is considered to be a variety of this species which is in the process of evolution into a new species. It has apparently already evolved to the place where it has largely lost its capacity to infect equines and ruminants, has gained the capacity to readily infect man, and in nature is transmitted by different species of tsetse flies than are utilized by *T. brucei*. Certainly, as a matter of convenience,



particularly to avoid confusion in terminology, it seems desirable for the present, at least, to retain the name *T. gambiense* for this physiological variety or species of trypanosome in man.

*T. rhodesiense* is generally believed to represent a more recent evolution from *T. brucei*, and perhaps even one that is currently evolving and not yet well established as a primary infection of man. It is separated largely on clinical and epidemiological grounds.

**Geographical Distribution.** Trypanosomiasis due to *T. gambiense* has a local and patchy distribution in tropical Africa. It is limited almost entirely by the distribution of its two principal vectors, *Glossina palpalis* and *G. tachinoides*. In general, it may be said to occur between 10° north and 10° south of the equator; it extends a bit farther north to Gambia and Senegal on the west coast but is scarcely found north of the equator on the east coast. The most highly endemic areas are along the Congo River and its tributaries in the Belgian Congo and French Equatorial Africa. Trypanosomiasis does not occur in the immediate coastal areas but inland it extends up to at least 3,500 feet elevation.

Trypanosomiasis has been carried by infected individuals to various parts of the world, but particularly to America in infected slaves. Nevertheless, in the absence of the appropriate vector, it has never become established anywhere outside tropical Africa. Within Africa it has continued to spread into new areas with migrations and development of new settlements, and epidemic outbreaks have occurred within the past decade. The introduction of the disease into a community where tsetse flies exist or the movement of noninfected immigrants into an endemic area is associated with a high mortality rate. In the endemic areas, as with malaria, reasonably good health for most of the populace is provided by immunity purchased at the price of a high mortality rate.

**Life Cycle.** The trypanosomes are slender, leaf-shaped or spindle-shaped extracellular parasites ranging in size from 15 to 35  $\mu$  long by 1.5 to 3.5  $\mu$  wide. They move rapidly with the aid of a conspicuous undulating membrane, which terminates in a single anterior flagellum. Upon staining with one of the Romanov's stains the large central nucleus and the smaller posterior kinetoplast are easily seen as red objects within the blue cytoplasm. Within the cytoplasm darker blue or purple volutin granules may be seen. Only this stage is known in man; it divides by longitudinal binary fission. Early in the course of the infection these trypanosomes may be found in the blood stream but later in the lymph nodes and still later in both the lymph nodes and the cerebral spinal fluid.

**Transmission.** Although prenatal infection and mechanical transmission by interrupted feedings of biting flies are both possible, neither plays any significant role in the epidemiology of the disease. Transmission is dependent upon tsetse flies (*Glossina*) in which there is biological development and multiplication of the parasites. The trypanosomes after ingestion by the fly undergo retrograde development to the crithidia or crithidiform stage as it multiplies by transverse binary fission in the midgut. After about 10 days they start growing back to the trypaniform stage and at the same time migrating toward the head end. About 20 days after the fly has become infected the so-called metacyclic trypanosomes are found in the salivary glands ready to infect man when the fly feeds again. These metacyclic trypanosomes

are somewhat more slender and the undulating membrane is less well developed than in the mature trypanosomes found in man.

*T. gambiense* is transmitted throughout most of its range by *Glossina palpalis* but *G. tachinoides* is an important vector in some areas, notably northern Nigeria, and *G. pallidipes* appears to be the principal vector in Uganda. *T. rhodesiense* is apparently transmitted primarily by *G. morsitans* but *G. swynnertonii* and *G. pallidipes* serve as vectors of local importance. *G. morsitans* is also the principal vector of *T. brucei*.

**Biology and Ecology of the Tsetse Flies.** The tsetse flies flourish only within a comparatively narrow range of temperature and humidity. The optimum climatic conditions appear to be afforded by 25° to 30° C (about 75° to 85° F) with 40 to 60 per cent relative humidity. Many die at temperatures above 35° C and few survive 40° C. Thus, during the hot dry seasons in the northern part of their range dense shade is indispensable for survival. On the other hand, when there is a very high relative humidity there is very little reproduction. The flies are ovoviviparous or larviparous. One larva matures at a time in the uterus and a total of 8 to 10 larvae are usually produced. The larvae immediately burrow into loose protected soil, often beneath stones or logs, and pupate. The pupal stage lasts from 20 to 40 days. Like the adults, the pupae are very susceptible to extremes of temperature and humidity. They are killed equally well by drying or by being constantly wet. Thus, the temperature and moisture requirements of both the adults and pupae largely restrict them to areas close to streams and lakes bordered by a heavy cover of tree or brush or both. The several species have their own precise requirements within these broad limits. *G. palpalis* prefers the heavy deciduous forests with heavy underbrush along rivers and lake shores. It does not persist in the dense evergreen forests. They must have high and fairly dry ground for pupation and do not survive in low wet areas. These flies are well adapted to feeding on man and domesticated animals. They will follow a possible blood meal for miles in the cover but do not venture far into the open. *G. tachinoides* survives better in less densely wooded areas and extends into the wooded savannahs of northern Nigeria. Although this species withstands hotter and drier climates than does *G. palpalis*, during such periods it is also concentrated in the more densely shaded riverine forests. *G. morsitans* is a woodland savannah species which also concentrates in wooded areas near water during the drier seasons; at other times, however, it roams widely over the more open grasslands. It appears to prefer wild game for food but readily feeds on domestic equines and ruminants and will attack man.

All species are daytime feeders primarily but will apparently also feed on bright moonlit nights. They rarely enter houses. Both males and females feed and transmit the infection.

**The Disease.** The flies bite so painlessly that the victim may be totally unaware of the attack. Later, however, the site may become indurated, erythematous, painful and, when subsiding, leave evidence of a lymphangitis. Sometimes the trypanosomes may be found in the skin shortly thereafter. In general, this is followed by an incubation period of weeks or months. The disease may be conveniently differentiated into the septicemic and neurotropic stages. The septicemic stage may last for months and is characterized by recurring bouts of remittent fever with headache and



lymphadenopathy. The most common suggestive sign is the characteristic enlargement of the postcervical chain; the nodes are soft but non-suppurating and painless. There may be evidence of toxic encephalitis and myocarditis; tachycardia is sufficiently frequent during this stage to be highly significant. Parasites can frequently be detected in the blood during the septicemic stage. This stage is not critical in uncomplicated trypanosomiasis. The neurotropic stage of the disease is ushered in with various neurological manifestations. Fever is less frequent and the lymph nodes gradually become fibrosed, and atrophy. Anorexia is common and the resulting malnutrition is believed to contribute significantly to the critical and fatal course of the disease. The troubles of this stage concern various cerebral functions and are by no means constant. They include aphasia, ataxia, personality changes, attacks of Jacksonian epilepsy, and paralysis agitans. These often do not develop for years in *T. gambiense* trypanosomiasis. The final stages are characterized by increasing attacks of somnolence, often with periods of nocturnal excitement. Cachexia usually develops before the patient becomes comatose and dies.

Trypanosomiasis due to *T. rhodesiense* develops much more rapidly. Parasites are more plentiful in the blood, adenopathy is less pronounced and there is little distinction between the septicemic and cerebral stages of the disease. It may run a fatal course in six months.

**Laboratory Diagnosis.** Most workers agree that microscopical examination of material aspirated from the lymph nodes is the most satisfactory method of detecting the parasites. Broden found 87 per cent of his verified cases by this method. Included in his series were cases without palpable nodes. The material may be examined fresh to detect the active trypanosomes or may be stained with one of the Romanovsky stains. Examination of the blood is usually considered unsatisfactory in *T. gambiense* infections but is more commonly positive in *T. rhodesiense* infections. However, there have been reports of finding the trypanosomes readily in thick smears and in centrifuged blood. Examination of the spinal fluid is practically much less than formerly. It appears to have some value late in the disease when the lymph nodes may be fibrosed and the parasites are principally in the central nervous system. Culturing, animal inoculation, and serological tests have been considered but their place in routine diagnosis is yet to be established.

**Prevention and Control.** (Buxton, 1948; Davey, 1948; Bequaert, 1946; Nasir, 1948a and b.) Personal protection includes avoiding the "fly areas" in the daytime, using repellents and protective clothing, and, so far as possible, traveling at night in fly areas.

Community-wide control has taken three basic courses: (1) direct attack on the fly; (2) maintaining a fly-free barrier; and (3) prophylactic treatment. The quarantine principle has been applied to some degree, at least, in connection with all these. In the *T. rhodesiense* and *T. brucei* areas the systematic destruction of game has also been practiced for the dual purpose of destroying the reservoir of infection and destroying the principal source of food for *G. morsitans*.

The direct attack on the fly has taken several forms but the destruction of suitable cover is perhaps the most common procedure, particularly in west Africa. For this purpose it is not necessary to destroy the forest but merely to clear the underbrush and in some cases thin the large timber. In some areas of Nigeria this has been facilitated by controlled burning. Burning not only destroys the cover for

dult flies but at the same time heat-kills the pupae. Despite its advantages for tsetse fly control it may prove to be ecologically undesirable in the long run and is perhaps less practiced now than formerly. Furthermore, burning the brush in *G. morsitans* territory may result in heavy grass growth which can actually improve some areas for this species. While destruction of forest cover for the flies is visualized as a means of attacking the fly, the same principle is used as a protective procedure. In the development of the Anchan rural resettlement in Zaria Province of Nigeria, a corridor 10 miles wide was cleared of fly breeding from the Zaria-Kano railway to the Zaria-Jos line 70 miles away. Resettlement was within this corridor and lines of communication could be traveled to the two railways in safety (Nash, 1948a). Similar provisions have long been made on a much more limited scale in protecting European developments in tropical Africa. Often it is sufficient for reasonable control to clear the immediate area in which living and working activities are carried on. Considerable success has resulted from clearing the brush and trees for a hundred yards or more around ferrying points, and even fording and bridge approaches to streams in the tsetse fly belt.

In some areas of Nigeria significant reduction in the fly population has resulted from the hand catching of flies by native boys. Trapping flies has also proved useful. Insecticides have not proved useful either in destroying the flies or interrupting transmission of the disease. Since the introduction of residual spraying both DDT and benzene hexachloride (gammexane) have been used in aerial spraying without much success. Periodic spraying and dipping of cattle to kill the attacking flies have also been tried without too much success.

Chemoprophylaxis is promising in prevention. Experimentally, a single dose of Bayer 205 (Surinam) appears to offer complete protection for at least three months thereafter and the more recently introduced pentamidine appears to offer such protection for at least six months (van Hoof, 1947). Accordingly, the use of these drugs is now a routine procedure in many areas, to at least supplement other control procedures. In some areas, notably the Belgian Congo, the use of these drugs, particularly pentamidine, has been administratively developed into a primary control procedure. Pentamidine is administered intramuscularly every six months in doses of 2 to 3 mg./kg.

A number of drugs, including Bayer 205 and pentamidine, appear to be therapeutically effective during the septicemic stage of the disease but so far only tryparsamide is dependable in the treatment of advanced cases of the disease.

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## AMERICAN TRYPANOSOMIASIS

(Chagas Disease)

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American trypanosomiasis, or Chagas disease, results from the accidental infection of man with *Trypanosoma* (*Schizotrypanum*) *cruzi* which appears to be a more common parasite of lower animals. The results of serological tests suggest that most human infections are benign or asymptomatic but in some areas, at least, it can produce serious disease. The parasite was first discovered by Chagas in 1909 in the insect vector, *Panstrongylus* (*Triatoma*) *megista*, and only later discovered in man and other mammals.

**Life Cycle.** In man and other mammals the parasite is known to exist in two stages, the trypanosome or trypaniform stage in the blood stream and the intracellular leishmania or leishmaniform stage, commonly in endothelial cells or the myocardium. The leishmaniform stages are oval and about 1.5 to 4.0  $\mu$  long and are indistinguishable from the parasites of the genus *Leishmania*. The trypaniform stage is characteristically bent into a C or U shape, is about 15 to 20  $\mu$  long, and can easily be distinguished from *T. gambiense* by the very large kinetoplast, which may even appear to extend beyond the limits of the cytoplasm in the stained specimen. Multiplication is by binary fission primarily in the leishmaniform stage. Rapid repeated divisions result in nests of these leishmaniform stages in the cell which give the suggestion of schizonts. It was this appearance that led to the name *Schizotrypanum*. The insect vector acquires the infection, apparently the trypaniform stages, by feeding on infected animals or man. Development in the insect is similar to that of *T. gambiense* except that the metacyclic trypanosomes ultimately are found in the hind-gut rather than in the salivary glands.

**Transmission.** Mayer, in 1918, reported that the bugs may remain infected for two years. The bugs characteristically defecate as they bite and in 1938 Cardo showed that the metacyclic trypanosomes from the feces of the bug were able to become established in experimental animals by penetrating the normal mucous membrane or the abraded skin. They did not succeed in penetrating the normal, intact skin and there was no transmission by biting. There is no pain associated with the actual feeding of the bug but an intense itching may develop as the proboscis is withdrawn. It is assumed, therefore, that human beings become infected through the mucous membrane, commonly the palpebral conjunctiva, or through scratching the parasites in the feces of the bug into the wound in the skin.

*Panstrongylus megista* is the principal vector in Brazil; *Triatoma infestans* in Argentina, Bolivia, Chile, and also important in Brazil; *Rhodnius prolixus* in Venezuela; and *Triatoma dimidiata* in Central America. *T. hegneri* and *T. gerstaeckeri* have been reported infected in Yucatan, Mexico. In the United States, at least eight species of the genus *Triatoma* have been reported naturally infected in Texas, Arizona, and California. *T. rubrofasciatus*, which is widely scattered in the Western Hemisphere and the Orient, has been found infected with the erithidia or erithidiform stages of flagellates indistinguishable from those of *T. cruzi*, but Floch and Abonnec, in French Guiana, and Deane, in Brazil, have shown that these erithidiform stages of *T. conorrhini* of the rat.

**Animal Reservoirs.** The infection has been found in a wide variety of wild and domesticated animals. These include the armadillo, opossum, ferrets, foxes, rats, and other small rodents, and one species of monkeys, as well as the dog, cat, and pig in South America. The opossum appears to be one of the commonest of the reservoirs but recently Neghme and Román (1948) found 13 per cent of the dogs and cats in Chile infected as compared to less than 2 per cent of the wild animals examined. In the United States the wood rat, as well as the opossum and armadillo, has commonly been found to be infected. In view of the report of *T. conorrhini* in rats, data obtained by xenodiagnosis should be reviewed.

**Geographical Distribution.** The demonstrated infection appears to be most common in man in southern Brazil, Uruguay, and across Argentina to Chile. Neghme and Román found 12 per cent of the rural population in central Chile positive on xenodiagnosis and 17 per cent positive on serological test. In Argentina up to 23 per cent has been reported. Human infections appear to be less common in the northern part of South America but have been reported, and the infection is comparatively common in animals. Up to 15 to 20 per cent human infection is reported in Bolivia. Only a few rare human infections have been verified in Central America and Mexico but serological tests in Panama suggest that it is not uncommon. No natural human infections have been reported in the United States but Packchanian (1943) infected a human volunteer with the flagellates from naturally infected *T. heidmanni* in Texas.

**Disease.** Apparently, most infections in man are harmless and asymptomatic. Difference in the severity of disease may well be, in part at least, a reflection of strain differences in the parasites (Hauschka and others, 1950). However, clinical cases have been reported from various areas of South America. While they appear to be more frequent in southeastern Brazil and northern Argentina, there are an increasing number of such reports from Venezuela, Bolivia, and other countries in northern South America.

The commonest early sign of the infection is a conspicuous swelling of the lids of one eye. It may be that when infection is through abraded skin rather than through the mucous membrane, the local reaction is so slight as to be overlooked. In Packchanian's experimental infection, by putting feces from an infected bug in the left eye, the lids of that eye became swollen, hyperemic, and painful in two weeks, reached its maximum severity by the eighteenth day and subsided in two more days. This was accompanied by a low-grade fever and enlargement of the axillary nodes; fever persisted for two weeks and nodes less than two months. Parasites were demonstrated in the blood from 21 to 84 days after infection. No cardiac disturbances were reported and the patient required no therapy. Apparently, many natural infections are no more severe but there is an increasing number of reports of cases with evidence of severe myocardial damage. Recent reviews by Torrealba (1946), in Venezuela, and Ponde (1948), in Brazil, stress the necessity of considering cardiopathy in Chagas disease and considering the possible causative relationship of *T. cruzi* to myocarditis in the endemic areas. Earlier suggestions that they may cause serious pathology of the thyroid have not been confirmed.

**Laboratory Diagnosis.** The parasites can be detected in the blood of human beings for only a short time. Inoculation of blood into culture media or laboratory animals is some improvement over direct examination. However, the best method



for actually detecting the parasites is by xenodiagnosis. In this test, laboratory-reared *Triatoma* are allowed to bite the individual to be examined and the crithidiform stages are recovered from the feces of the bug after multiplication. Deane (1947) calls attention to the fact that using this technic to survey rodents may lead to error through recovering the crithidiform stages of *T. conorrhini*. The complement-fixation reaction has been used both clinically and in surveys. Its uses and limitations have been reviewed by Hauschka and others (1950).

**Prevention and Control.** The only practical approach is through preventing attack by the triatomines. The bugs apparently have no preference for human blood but will attack man freely if given the opportunity. They find shelter in brush piles, lumber piles, or in accumulated debris. It is significant that most of the infections are in rural areas among people of the lower economic groups. Debris under and around the dwellings of such houses affords excellent harborage for the bugs; cleaning up such debris affords a large measure of protection. Neghme has found as high as 90 per cent reduction in the bugs as a result of one application of DDT but reports that benzene hexachloride (gammexane) is probably superior (see Chapter 7).

No therapeutic agent has been consistently successful so far.

**Other Trypanosomes in South America.** *T. rangeli* was originally discovered in *Rhodnius prolixus* in Venezuela and has since been reported in several other countries in South America. Pifano (1949) has recently studied the infection in humans. He reports that *T. guatemalensis* is a synonym. More recently *T. ariari* has been reported as a human infection in Colombia (Renjifo-Salcedo and others, 1949). Both *T. rangeli* and *T. ariari* appear to be quite distinct from *T. cruzi* but since both infect man and both utilize triatomines as intermediate hosts, it is not clear to what degree they have been confused with *T. cruzi* in earlier work.

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Leishmaniasis exists in three rather well defined clinical forms. The causative agents, *Leishmania*, are round to oval parasites 2 to 4  $\mu$  long. They are morphologically indistinguishable from each other and from the leishmaniform stage of *Trypanosoma cruzi*. They are classified with *Trypanosoma* in the family Trypanosomidae. Three specific names are usually given to the organisms which cause the three different forms of the disease. They are distinguished by tissue preference and resulting clinical manifestations and geographical distribution. There is also a limited amount of work on serology and biology which tends to support this classification. However, it has been reported that *Leishmania* from either the cutaneous or visceral form of the disease may produce both visceral and cutaneous infections in dogs. Kirk (1949) has recently reported that a strain of *Leishmania* isolated from a human case of visceral leishmaniasis in the Anglo-Egyptian Sudan produced visceral, cutaneous, and mucocutaneous lesions in monkeys. Furthermore, a few cases of visceral leishmaniasis occur annually in South America and those areas of the Near East, India, and south China where the disease is usually in the form of mucocutaneous or cutaneous leishmaniasis. Nevertheless, it is generally agreed that there are advantages in retaining the following specific names for the diseases indicated:

*Leishmania donovani* (*L. infantum*; *L. chagasi*), the cause of visceral leishmaniasis;

*L. tropica*, the cause of cutaneous leishmaniasis;

*L. brasiliense*, the cause of mucocutaneous leishmaniasis.

#### VISCERAL LEISHMANIASIS (Kala Azar, Dum-Dum Fever, Black Fever)

Visceral leishmaniasis is primarily an Old World infection. In the Mediterranean area it occurs principally as a disease of infants and very young children, hence the names infantile kala azar and *L. infantum*. It seems unlikely, however, that this age distribution is associated with a species characteristic. The infection occurs along the Mediterranean coast of Morocco, Tunis, and Algiers in Africa, and, in Europe, along the Mediterranean coast of Spain, a limited area of France around Marseilles, the southern tip of Italy, and a limited area of Yugoslavia east of the Trieste area, and Greece. It is also found on the Islands of Malta, Sicily, Crete, and the adjacent Greek Islands. In the Mediterranean area it appears to be most severe in Sicily and Italy. In Africa, kala azar occurs also in the Anglo-Egyptian Sudan and, to a lesser extent, in Abyssinia and northern Kenya. Adler (1947) found that the Sudan strain is biologically similar to *L. infantum* \* of the Mediterranean, despite the difference in the age groups attacked. In these areas, as in Asia, the disease occurs in adolescents and adults rather than in infants. Foci of infections occur in Transcaucasia, Turkistan, and east of the Caspian Sea to India. Although the disease is the most severe and the most widespread in India, even here it is restricted to the eastern side of the peninsula. Although it occurs as far south as Madras, the principal infection is north of the head of the Bay of Bengal in Assam, Bengal, Bihar, and the United Provinces as far west as Lucknow. It is endemic in much of this area and attacks

\* These workers retain the two specific names *L. donovani* and *L. infantum*, the latter being applied to the Mediterranean and Sudanese strains.



principally the 10 to 14 year age group. Epidemic waves occur and Napier points out that during the past half century there have been three epidemic waves in Assam and each succeeding wave has penetrated further up the Assam valley. There is no extension of the infection east of Assam and it occurs elsewhere in Asia only in China from the Yangtze Valley north into Manchuria; there have been reports of the infection in inner Mongolia. Infection in this area appears to be even less restricted to the younger age group than in India. The infection has never been reported in the Pacific east of the Asiatic mainland.

A few cases of visceral leishmaniasis occur each year in South America; the use of the viscerotome in examinations for yellow fever in Brazil and Argentina has revealed less than 0.1 per cent infection.

**Life Cycle.** Only the nonflagellated leishmaniform stage is known in mammals. It is strictly an intracellular parasite occurring commonly in the endothelial cells, various glands and organs. In some areas it is reported commonly in lymph nodes. Multiplication is by repeated binary fission. While these leishmaniform stages have been recovered from feces, urine, and nasal secretion, they are so poorly prepared to survive in the external environment that transmission by these means is usually discounted.

Epidemiological evidence has incriminated sandflies, *Phlebotomus*, but only occasional infection was established in the laboratory before Smith and his co-workers in 1941 discovered that infections would not regularly develop unless the flies were permitted to feed on plant juices after feeding on the infected man or animal; the same year Adler and Ber (1941) showed that the flies could be induced to ingest *Leishmania* from culture only if diluted with 2.5 per cent salt solution. It has since been amply established that in the midgut of the flies, as in culture, the parasites develop into the flagellated leptomoniform stage. The parasites return to the mouth parts and man is infected by the bite of the fly. *Phlebotomus argentipes* is the principal vector in India, *P. major* and *P. perniciosus* in the Mediterranean and *P. major chinensis* in China. More than a dozen species viciously attack man in Sudan but Kirk and Lewis (1947) report that only *P. langeroni orientalis* has a distribution similar to that of kala azar. Corradetti has reported that *P. perfiliewi* is a vector in southern Italy.

**The Disease.** The incubation period is generally believed to be one to three months but there are cases reported to have developed in less than two weeks after arriving in the endemic area and as long as a year and a half after leaving it. The onset may be abrupt with a malaria-like paroxysm, but more commonly with a rapidly mounting temperature or even so insidious that the patient can scarcely recognize his initial illness. Anemia and leukopenia regularly occur; the leukopenia is due primarily to a reduction in the granulocytes; a relative, and often an absolute, monocytosis occurs. There may be recurring bouts of fever and headaches for months; recurrent diarrhea is common. The spleen and liver both become enlarged and tender. In China and the Sudan, lymphadenopathy is reported to be common. Napier emphasizes that this is unusual in India. Emaciation with edema of the extremities is seen in advanced cases. Untreated cases in epidemics have been associated with 75 to 90 per cent mortality. Most and Lavielles (1947) have reviewed the clinical course of the disease in American soldiers.

Recovery from the acute phase of the disease may be followed by the app-

ence of pigmented cutaneous nodules as much as a year or more later. This is most commonly reported from India. Parasites may be detected in these nodules.

**Laboratory Diagnosis.** Detection of the parasites is not easy. The examination of the blood is particularly unsatisfactory but Napier reports that they are usually present in the blood of the clinical case and continued search should reveal them in macrophages or lymphocytes. Parasites may be more readily found in aspirates from the spleen, lymph nodes, and bone marrow. The latter is more commonly used. Any of these materials may be inoculated into culture (NNN medium) or animals (hamsters) but a month or more may be required to confirm the diagnosis. Several tests have been developed which depend upon the increased euglobulin content of the serum during the disease. The aldehyde test is the simplest; one or two drops of formalin are added to 1.0 ml. of serum and it becomes solid and opaque within a few minutes to 24 hours. The antimony tests depend upon layering a solution of one of the pentavalent antimonials (4 per cent urea stibamine in the Chopra test) over diluted serum; a flocculent precipitate is formed at the interphase.

**Epidemiological Factors.** In India, apparently there are no significant animal reservoirs but in both the Mediterranean area and in China the dog appears to be important. The flies attack man viciously in the shaded forests both day and night but in more open country enter houses to feed primarily at night. The flies pass larval and pupal stages in moist sandy soil, protected from direct rays of the sun. In nature, hollow trees and other protected wooded spots are used but the flies have become well adapted to shelter provided under houses, between buildings and in abandoned buildings. The disease is almost entirely rural or semirural but excursions into villages or margins of larger cities are common.

**Control.** Attempts to attack directly the diffusely scattered breeding spots does not appear to be feasible. DDT spraying of houses has been reported to be highly effective in the destruction of *Phlebotomus* in Abruzzi, Italy (Corradetti, 1949), and in preventing the transmission of infantile kala azar there. This use of residual sprays has apparently not been extensively employed in India and China and arguments have been advanced against its chances of success there. However, since it has been successfully used to control phlebotomi which transmit pappataci fever in the Mediterranean area and American leishmaniasis and bartonellosis in Peru, it seems probable that residual spraying has not had sufficient trial against kala azar. The flies are so small that screening of houses and the use of bed nets offer relatively little protection unless a very fine mesh is provided.

Isolation and treatment are considered to be significant control procedures in India.

A number of pentavalent antimonials are effective but a long course of treatment is required; these include neostibosan, stibanose (solustibosan), urea stibamine, and stibamidine.

### CUTANEOUS LEISHMANIASIS

(*Oriental Sore, Old World Cutaneous Leishmaniasis*)

Oriental sore is perhaps most commonly seen in the Near East and eastward into northwest India. The local names, Bagdad boil, Aleppo boil, Lahore boil, and others reflect the localized nature of the endemic areas within this broad zone. In general, the distribution is quite different from that of kala azar but the two overlap in the



Mediterranean area and in Transcaucasia and Turkestan. The disease appears to be spreading northward in the latter areas. In Africa, it is found in Egypt and extends up the Nile to Sudan but has been reported from along the Mediterranean coast as far west as Morocco. It appears to be relatively rare in Europe but Corradini (1948) has reported that it is of frequent occurrence in Abruzzi, Italy, where infantile kala azar is also common. He reports nearly 3.0 per cent with active infection and over 20 per cent with healed cutaneous scars in one survey. In the Far East the disease has been reported from south China and Indochina; a few cases have also been reported from Queensland, Australia. In general, the infection is found in drier country than is kala azar, due apparently to the fact that the principal vectors prefer the dry areas.

**The Disease.** The incubation period is not constant; it is said to vary from a few weeks to several years. The characteristic lesion is initiated as a granular nodule which ruptures into an open ulcer, usually on an exposed part of the body. The lesion may remain circumscribed and after a year or more may heal with a permanent, often disfiguring, scar. Often, however, they enlarge into the eroding type of ulcer. Multiple lesions are common and while they may result from contact, the spread to new sites is apparently usually by way of the lymphatics (Ansari and Mofidi, 1950).

Secondary bacterial infection may occur and actually kill the parasites so that the characteristics of a pyogenic lesion develop.

**Laboratory Diagnosis.** The organisms can usually be detected by smears made from the base of the ulcer; it is essential to get beneath the necrotic tissue to live cells in obtaining material for the smears. Steinhauer has recently reported that an interdermal test will detect up to 97 per cent of the cases.

**Transmission and Epidemiology.** The infection is transmitted biologically by *Phlebotomus* in the same manner as kala azar. In the Mediterranean area, the Near East and India the principal vectors are *P. papatasi* and *P. sergenti* but *P. macedonicum* has also been incriminated in Italy. The infection in the Near East is most common among the poor, being particularly common among the beggars. It is possible that contact infections may occur or that it may be transmitted mechanically by flies which swarm on the sores under these circumstances. However, the organisms appear to be unable to penetrate the skin and would have to reach an abrasion. Certainly, the infection is not maintained in the absence of the biological vector, *Phlebotomus*.

Dogs serve as a reservoir of infection near human habitations and particularly in village or urban areas. Wild rodents, particularly the gerbil (*Rhombomys opimus*), serve as the reservoir in rural areas. Since the sandflies commonly live in the burrows of these rodents they have a high infection rate in such places and are to be avoided.

**Control, Immunity, Treatment.** Upon recovery from the infection, either spontaneous, or as a result of therapy, the individual is usually thereafter immune. Recognition of this centuries ago resulted in the local practice in certain areas of the Near East of deliberately inoculating newborn babies with material from open ulcers. Apparently there was sufficient prenatally acquired immunity to prevent extensive ulceration and sufficient infection developed to subsequently protect the individual. This has not been developed into modern public health practice. However, A.

and Zuckerman (1948) have found that when phenolized parasites from culture are inoculated and followed by living organisms from culture, a localized and transient immunizing infection results. So far, a highly protective immunity has resulted only from infections. Since it may be necessary to treat the immunizing infections the procedure has not been given extensive public health trial.

Residual spraying with DDT should have value, particularly in localized community infections in villages.

Pentavalent antimonials are effective both topically and intravenously. Trivalent antimonials appear to have the greatest value when applied topically.

#### MUCOCUTANEOUS LEISHMANIASIS

(*American Cutaneous Leishmaniasis, Espundia, Chiclero Ulcer*)

Although mucocutaneous leishmaniasis has been reported in the Old World, notably in the Anglo-Egyptian Sudan, the designation is usually given to the disease if it occurs in South America. While the mucocutaneous lesions, particularly involving the lips or the nose, may be said to characterize the disease, they are by no means the only lesions found. In Peru, where Weiss says the disease rivals malaria, initial lesions are most commonly on the exposed skin similar to those of Old World mucocutaneous leishmaniasis. This is followed in many cases by secondary lesions or direct extension to the mucocutaneous junction. Goldman (1947) has reviewed and amply illustrated the disease. In Yucatán Peninsula, Mexico, the lesions show a peculiar distribution, occurring usually on the lobe of one ear.

The disease appears to be most common in northern Argentina, Brazil, Bolivia, and Peru but has been reported in all other countries of the northern part of South America. It has been reported from Panama but is not common and apparently does not occur elsewhere in Central America or Mexico, except on the Yucatán Peninsula where it is confined to the chiclero workers. It rarely occurs in women or children in this area. Pessôa and Barretto (1946) report that in parts of Brazil the infection is largely restricted to woodsmen. In Peru, the infection is contracted both in such areas and in villages.

Transmission is by sandflies and *P. intermedius* is common in eastern and northern South America. More work is needed to more sharply indicate the species involved. Animal reservoirs may well exist but relatively few dogs and cats have been reported infected. The wild animals have not been extensively studied.

**Control.** Hertig and Fairchild (1948) have shown that DDT will effect complete control around human habitations in Brazil. Since the flies move by a series of short, hop-like flights, even a residual outside the houses, on window sills and harborage areas, such as stone walls, will protect the occupants from infection and effect reduction in the flies. These workers point out that recovery of the fly population is slow and, thus, the results of a single spray may have long-lasting effects. The protection of the chiclero workers in Yucatán and those who work in the woods in Brazil and Peru is more difficult. Protective clothing including head nets are indicated when flies are plentiful. Repellents may be used.

As for cutaneous leishmaniasis, the antimonials are the preferred therapeutic agents.



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## PHLEBOTOMUS FEVER

(Pappataci Fever, Sandfly Fever, Three-Day Fever)

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Phlebotomus fever is an acute specific infection, caused by a filtrable virus conveyed to man by the bite of *Phlebotomus papatasi*. The disease was described by Pym in 1804. Doerr and his co-workers, in 1909, showed that the virus was present in the blood of patients during the first day of the disease, at which time it can be picked up by *P. papatasi* females feeding upon the patient. Following an extrinsic incubation period of about five days or more, the flies are able to transmit the virus by the bite. The length of time that the flies remain infective does not seem to have been established.

The period of incubation is three to five days. The disease is characterized by sudden onset, fever lasting two or three days, headache and aches in the body. Uncomplicated cases are never fatal. The disease occurs in epidemics with a high incidence rate, and so may cause considerable loss in effectiveness among troops, laborers, and other groups of people. Clinically, it resembles influenza and dengue. Convalescence is slow, requiring three to four weeks. Diagnosis is based upon clinical and epidemiologic evidence (Sabin, Philip and Paul, 1944). Phlebotomus fever may be suspected when there is an outbreak, within the range of the vector, of illness with fever of short duration among soldiers, immigrants, or other newly arrived groups of people. Sabin's studies (1948) indicate that there are at least two strains of the virus which are unrelated immunologically. One attack by a given strain confers a solid immunity for at least two years, and possibly much longer.

Within endemic areas, adults and adolescents are largely immune; presumably this immunity is acquired by infections occurring during infancy or childhood.

Phlebotomus fever is prevalent in the Mediterranean region, the Middle East, provinces of Central Asia in the USSR, and the northwest and central provinces of India. It has been reported from Mexico, Central and South America, but so far as known at present, *P. papatasi* is the only vector and as this species does not occur in the Americas, the infections in the neotropical countries may have been misdiagnosed cases of atypical dengue or other febrile disorders. Experiments on the capability of other species of *Phlebotomus* to transmit this or related viruses would be of interest.

The mechanism of survival of the disease from one epidemic season to the next is unknown. The virus disappears quickly from the blood of the patient; immune persons apparently are not infectious to the flies; there are no known reservoir hosts, and survival in the adult fly is thought to be impossible because the adult is not supposed to be capable of hibernation. The winter season is said to be passed by *Phlebotomus* in the larval stage. It has been claimed by some workers that there is a hereditary survival of the virus in the flies, which would account for interepidemic survival, but Sabin was unable to obtain infected progeny from infectious females. It has been suggested that larvae might acquire the virus by feeding upon the dead bodies or excreta of infected adult flies, but other workers have observed that the larvae do not feed to any great extent upon these substances. Young and his associates found mites attached to a number of adult *P. papatasi*, and present the theory that these arachnids might be the reservoir of the virus, passing it on to the flies, which, in turn, may infect man. There is no evidence to support this hypothesis.

Treatment of phlebotomus fever is symptomatic; there is no specific therapy. Prevention depends upon the control of sandflies, especially through the use of residual insecticides in human dwellings. Protection may be obtained through the use of repellents.

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#### BARTONELLOSIS

(*La Verruga, Oroya Fever, Carrión's Disease, Verruga Peruana*)

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Bartonellosis is an infectious disease caused by a pleomorphic bacterium, *Bartonella bacilliformis*. The disease is limited to the river valleys of both slopes of the Andes in Peru and adjacent countries at elevations from 1,500 to 9,000 feet. It is possible that the disease which beset the Spanish conquistadores in this area was bartonellosis but the first established epidemic was in 1870, when about 7,000 workmen died of the disease in the building of the railroad in the Oroya River Valley. Epidemics still occur when nonimmunes are quartered in the endemic areas. The infection was apparently introduced into Colombia in the middle 1930's, re-



sulting in a highly fatal epidemic in 1935. The disease is also reported from Ecuador.

**Vectors and Reservoirs.** The disease is transmitted by sandflies. *Phlebotomus verrucarum* is the only demonstrated vector and its distribution in Peru coincides with the distribution of bartonellosis. It is a nocturnal form and freely enters human dwellings to attack man at night (Hertig, 1942). Two other species have been found in parts of the endemic areas but appear to be unimportant. *P. peruvianus* feeds indifferently on man and animals but shows no preference for man; it frequents caves and apparently feeds on lizards. It is absent from some of the most important endemic areas. *P. noguchi* does not associate with man particularly; rarely enters either human dwellings or stables. It appears to prefer field mice and is found in caves and mouse burrows. *P. verrucarum* has not been reported in Colombia but Rozeboom (1947) found an almost indistinguishable form, *P. Colombianus*, to be the principal species present in collections from the endemic area.

No animal reservoirs have been found. Monkeys have been experimentally infected but the usual laboratory animals are refractory.

**The Disease.** The incubation period is usually three to four weeks but may be more than three months. The disease occurs in two distinctive stages, the septicemic or Oroya fever stage followed by dermal lesions or the verruga stage. The relationship between the two was not recognized until Carrión, in 1885, inoculated himself with blood from a verruga nodule and died five weeks later from Oroya fever.

The septicemic stage is characterized by headache, general malaise, an irregular remittent fever and rapidly developing anemia. The red cell count may drop below 2,000,000 in less than two weeks. This is associated with a marked enlargement of both spleen and liver; generalized lymphadenopathy is also usual. The organisms can usually be seen as rods in the red cells during this period; they may be cultured from the blood as well. In epidemics the case fatality rate is from 40 to 90 per cent. Death usually occurs within three weeks of the onset. If the patient survives three weeks, convalescence and the dermal lesions or verruga develop; the verruga may not appear for a month or more. Even in epidemics the septicemic stage may be mild as to pass unnoticed and the verruga stage alone may appear as the only obvious sign of the disease. It is a popular belief that the development of verruga assures ultimate complete recovery. The dermal lesions may be either military or nodular. Both suggest hemangioma and the nodules have a marked tendency to rupture. There may be successive crops over a period of a month or more. Organisms may be recovered from the skin lesions.

Until the advent of the antibiotics there was no satisfactory treatment. Chloramphenicol is reported to be effective (Urteaga and others, 1955).

**Prevention and Control.** Since the principal vector, *P. verrucarum*, is a nocturnal biter particular protection should be taken at night. A fine mesh bed net is required to exclude these insects. Repellents may prove more useful. He reports that since 1909 it has been the practice of the railroad company not to quarter its personnel within the endemic area at night. Since these areas are quite localized it may require moving only a few miles to a camp site free of the insect.

Hertig and Fairchild (1948) have found that DDT applied to dwellings, stables, walls, old buildings, and other man-made resting places will prevent transmission and produce a marked reduction in the fly population for a year or more.

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PLAGUE

Since the dawn of history, bubonic plague has been known to be one of the major pestilences of mankind in some parts of the world. Numerous writers described the manner in which it spread in devastating epidemics. Up to the turn of the past century efforts to explain these phenomena were shrouded in mysticism and demonology or vaguely attributed to miasma, but a discriminating minority held to the idea that the disease was contagious. The association of an epidemic in human population with a concurrent high mortality enzootic among rats was repeatedly observed but its significance was not grasped.

Belief in the vital importance of the rat in plague was not generally accepted until a decade after Kitasato and Yersin in 1894, working independently, discovered the causative agent, *Pasteurella pestis*. A French epidemiologist, P. L. Simond, in 1897, reviewing the available evidence and the manner in which the disease was disseminated in Bombay, postulated the concept that bubonic plague was primarily a rat disease and that man played only a secondary part in the spread of the infection and that transmission from rat to rat and from rat to man was effected by fleas. The validity of this postulate was confirmed and its implications elaborated by other investigators. Urban plague was found to involve commensal rats and the tropical rat flea, *Xenopsylla cheopis*; rural plague (sylvatic) a variety of wild rodents and of many flea species. This did not exclude the consideration that *P. pestis* may occasionally be transmitted directly from man to man by air-borne nuclei causing epidemics of pneumonic plague nor, on the other hand, that plague infection may smolder for years in a wild rodent population with only a sporadic transmission to man.

Even after the discovery of the rat (*Rattus norvegicus*, *R. rattus*) as a reservoir host of *P. pestis* and the flea as the principal vector, the efforts of health authorities to halt the march of epidemics were singularly ineffective. The control of plague presented a problem of great complexity which required for its solution an intimate acquaintance with all the factors governing the fourfold relationship of man, microbe, rat and flea. The prevalence of plague in any particular community is affected by the habits of a variety of rodents and their fleas, and they in turn are influenced by climate, harvest, and a number of other changes in environment.

**Plague in Rats.** Where conditions are favorable for the spread of plague, sick and dying rats are often noticed some days prior to the onset of the initial human cases. Sometimes, however, the diagnosis of a human case is the first evidence that the disease is present. Under such circumstances sick or dead rats usually will be



found upon searching premises where the infection might have been contracted either the home, place of occupation or nearby premises. Many cases of plague receive their infection through handling dead rats during an epizootic of plague in ignorance of it. Sick rats apparently crave water which accounts for their being seen in the open and often dying away from their nests.

Plague among rats acts differently depending on whether it is an initial infection, also whether it is in large or small communities and upon many other factors. In small communities, where the conditions are particularly favorable, plague spreads with such rapidity that it may destroy nearly the entire rat population and then burn out for lack of material. In large cities these severe primary epizootics last long and die down but not out, and increase again in severity at later periods. With the continuance of plague in such places, as time passes there is a noticeable decrease in the number of dead rats found and also a decline in the disease in man. There is little doubt that the explanation of diminished rodent plague is directly connected with an increasing immunity of the rat population. The Indian Plague Commission found that 59 per cent of the rats in Bombay were immune to plague, whereas rats of Madras showed slight immunity. In San Francisco, McCoy also showed that 15 per cent of small rats and about 50 per cent of large rats were immune to highly virulent material.

Plague infection in rats is characterized by engorgement of the subcutaneous blood vessels and a diffuse pink color of the subcutaneous structures and muscles. The diagnosis may often be inferred at the first incision. The lymphatic glands of the neck, axilla, groin or pelvis are enlarged and frequently surrounded by a hemorrhagic exudate and edema. The liver is granular with focal necroses, the spleen enlarged and friable, and pleural effusions are common. All of this pathological picture is seldom found in a single rat.

In subacute cases or when rats are recovering from infection and resolution is taking place, often referred to as chronic plague, the pathology is somewhat different. In this type the lesions consist of purulent or caseous foci, usually in the abdominal viscera; that is, they occur as splenic nodules and abscesses, or mesenteric abscesses. Sometimes abscesses are situated in the regions of the peripheral lymphatic glands. Plague bacilli are either absent or very scanty upon microscopic examination of the abscesses, but may be recovered by cultural methods or more surely by guinea pig inoculation.

The macroscopic appearance of guinea pigs is somewhat similar to that described for rats except that the gelatinous hemorrhagic exudate and enlargement of the inguinal glands are more marked and the spleen is generally filled with small abscesses. If the guinea pig dies in four days or less the abscess condition of the spleen may not be present but plague organisms will be found in enormous numbers in the organs and the blood. When a guinea pig lives eight days or is killed on the tenth day, these findings are of the resolving type noted in rats.

**Plague in Fleas.** As observations and experiments accumulated it became evident that different species of fleas varied greatly in their efficiency as natural vectors of human plague. In any particular locality it was determined by their numbers, dispersion, rodent hosts, tendency to attack man and other factors. When a flea takes a blood meal on a rodent host with an infection in the septicemic phase

plague bacilli are introduced into the alimentary tract and find conditions in the lumen of the gut favorable to multiplication. In some flea species the mass of rapidly growing micro-organisms in the proventriculus becomes so large that additional food is blocked from passage and the flea dies of starvation. It was formerly thought that the plague organisms passed through, and infection of rodent or man resulted from scratching the flea bite and contaminating the wound with infected feces. Now it is accepted that the infected flea regurgitates the bacilli into the wound as it feeds. This blockage phenomenon is characteristic of those species that are efficient vectors of *P. pestis* (Eskey and Haas, 1940). There is no trans-arterial passage of these micro-organisms from one generation of fleas to the next.

In an infected plague focus the epidemic potential may be determined in part by the number of fleas of the vector species. Attempts have been made to standardize a quantitative index in terms of the average number per rat (Hirst, 1953).

**Sylvatic or Campestral Plague in North America.** In August, 1903, a black-footed rat died of plague contracted from a squirrel in Contra Costa County, California. In 1904, Currie demonstrated the susceptibility of the ground squirrel to bubonic plague. In 1908, McCoy and Wherry discovered natural plague in ground squirrels. It was then learned that thousands of squirrels had died of some disease during 1904, 1905 and 1906. This epizootic was doubtless plague. Since then the infection has continued endemic among the ground squirrels.

California is overrun with three species of ground squirrels, of which the commonest is *Citellus beecheyi*. They live in colonies in burrows or warrens. The screech owl which is a frequent companion in their burrows may spread infected fleas. Owls give the infection to squirrels and the squirrel flea (*Ceratophyllus acutus*) then passes the disease among them. This flea will also attack man just as do rat fleas. The infection may also be conveyed to man through squirrel bites, as in the case of a child in Los Angeles studied by Stimson. Squirrels make good food for man but since the danger has been realized the shooting or trapping of them for food purposes has been forbidden in California.

An outbreak of pneumonic plague in Oakland, California, during August and September, 1919, started with a man who went squirrel hunting in the Berkeley Hills on August 11 and 13, and took ill August 15. The outbreak involved 14 cases, 8 of whom died (Kellogg, 1920). Another localized epidemic of the same type, but more extensive, occurred in Los Angeles in November, 1924. In this episode it is believed that the squirrels gave the infection to rats which in turn passed the disease on to a man who started the pneumonic epidemic.

Plague in the squirrel may be recognized by the gross anatomical lesions in the lymphatic glands, the liver and lungs. Involvement of the lungs is common in the squirrel. Many cases are subacute or chronic. Smear preparations from squirrels dead of plague are frequently negative for plague-like bacilli. The diagnosis may, therefore, be made by subcutaneous inoculation which is surer than the cutaneous method, as the latter often fails on account of the comparatively few plague bacilli present in squirrel lesions.

Squirrels may be destroyed by various means. At the present time, thallium sulphate-poisoned grain is superseding former methods. Placing carbon disulphide in burrows either by means of spray or on cotton and then closing the opening is an



effective method. Shooting and the use of grain poisoned with strychnine, phosphorus, or cyanide of potassium have destroyed many squirrels in California. They are not successful. Natural enemies are the coyote, wolf, badger, skunk, mountain lion, cobra snake, and the red-tailed hawk.

**Plague in Man (Peste).** Plague is an infection primarily of rats and other rodents, secondarily of man; caused by *Pasteurella pestis* (*Bacillus pestis*), a hemorrhagic septicemic organism. When the hemorrhages occur in the skin they are called "plague spots," which gave the name "black death" to the disease in the middle ages. In addition to this specific definition, the term "plague" still has a general meaning. There is much confusion in the literature, because formerly all serious epidemics were called plagues and we still speak of them as plagues.

There are two chief forms: bubonic and pneumonic.

**BUBONIC PLAGUE.** Bubonic plague is the common type of the disease. It is characterized by fever, depression, great prostration, and painful, tender inflammatory enlargements of the lymph nodes (buboes). The glands of the groin are most commonly affected (54 per cent) due to flea bites of the legs; next those of the axilla, then the head; occasionally multiple. When suppuration takes place it is regarded as a favorable sign. There is a high leukocytosis. The period of incubation is usually five to seven days. In this type the plague bacillus is locked up and is not eliminated in the body excretions. Bubonic plague, therefore, is not directly contagious from man to man.

The seasonal prevalence of bubonic plague varies in different localities and under other factors. Epidemics tend to subside when the mean temperature reaches 85° or falls below 60° to 55° F. In other words, in a hot climate epidemics flourish in the late winter and spring, to subside in hot weather, while in cool climates they are generally most severe in summer and decline with the onset of cold weather. Robertson (1923) has shown that in countries with a mean midwinter temperature of 45° F or below, bubonic plague is occasional, accidental and distinctly limited. It is essentially a disease of the tropics and subtropics, flourishing best in moderately warm, dry weather. Unfavorable weather conditions, such as heavy rains that flood exterior harboring places of rats, and the return migration of rats to buildings with the end of the crop season cause an increase in human plague of a seasonal character. The geographic distribution and seasonal prevalence correspond closely to the number and activity of the chief flea transmitter of the disease, *Xenopsylla cheopis*. In some localities there are other species of fleas which affect the seasonal prevalence, but these fleas have not been spread throughout the world as *Xenopsylla cheopis*.

**PNEUMONIC PLAGUE.** Primary pneumonic plague resembles croupous pneumonia except that the sputum is more bloody and less tenacious. The causative bacterium, *P. pestis*, appears in enormous numbers in the sputum. Few recover, death usually occurring in two to four days. The period of incubation is short, one to three days. The disease is highly contagious and usually is transmitted by close association, droplet or contact infection.

A secondary pneumonia may develop during the course of an attack of the bubonic type. Primary pneumonia may assume alarming epidemic proportions. In Manchuria in 1910-11 (60,000 deaths). This epidemic took place in winter.

and was one of the most virulent epidemics of modern times, the case mortality being almost 100 per cent. Other extensive epidemics have occurred, notably in central China in 1917-18, 15,000 deaths, and a second outbreak in Manchuria in 1920-21 with 9,000 deaths. A limited outbreak, which started from an infected squirrel, was reported in California in 1919 and a somewhat larger epidemic in 1924. It is generally believed that plague contracted from animals other than the rat, such as the tarbagan and squirrel, is apt to develop the pneumonic rather than the bubonic form.

**SEPTICEMIC PLAGUE.** The septicemic form of the disease is due to an overwhelming infection of the blood with the plague organisms which kill before the buboes have time to appear. Hemorrhages are common.

**PESTIS MINOR.** Pestis minor, or ambulant plague, is a mild form of the disease with fever and buboes which may suppurate, but with symptoms so slight that the patient does not go to bed.

**OTHER FORMS.** An intestinal form of plague occasionally occurs, causing diarrhea and the features of typhoid fever. In another type, skin lesions appear as vesicles and then pustules which might be mistaken for smallpox. Plague bacilli are present in the lesions. There is also a tonsillar type due to killing infected fleas with the teeth.

**DIAGNOSIS.** The diagnosis is made from the clinical symptoms, by finding the bipolar bacilli in material aspirated from the buboes; or in smears of the sputum in the pneumonic type. Some cases require guinea pig tests for diagnosis. In plague cases every illness associated with enlarged glands and all cases of pneumonia demand critical examination to avoid mistakes.

**HISTORY.** A comprehensive account of the history of plague has recently been published by L. Fabian Hirst (1953). The Philistines made offerings of golden images of the mice that marred the land and of their emerods to stay a pestilence. The epidemiology of this outbreak, which started on the seacoast at Ashdod and moved inland, smiting at Beth-shemesh 50,070, is clearly described in I Samuel, 4. The plague of Athens and the pestilence in the reign of Marcus Aurelius, according to Payne, may not have been this disease. Epidemics of varying severity occurred in Europe for over 1,100 years, from the sixth century in the days of Justinian to the middle of the seventeenth century. The most devastating was the "black death" of the fourteenth century which overran Europe and destroyed one-fourth of the population. The disease gradually subsided and disappeared from Europe but continued to be endemic in a few remote parts of the world. Suddenly, in 1894, it reappeared in Hong Kong and from there again spread over the world. This recrudescence of the disease thought to be geographically limited is one of the most striking facts in its epidemiology.

In 1664-65, the black death in London carried off 70,000 of a population then numbering 500,000. A graphic though imaginative description is given by Defoe in *Journal of the Plague Year*. Numerous references to the disease will be found in Pepys's *Diary*. Benvenuto Cellini describes his own case in his autobiography. The disease profoundly affected the economic, social and political history of Europe. Plague started in Stratford-on-Avon in July, 1564, when Shakespeare was a baby three months old. From July to December of that year, 237 deaths are recorded in



the parish register of the little vicarage of Avon. The infection swept away entire families.

**THE RECENT PANDEMIC.** The recent pandemic is the most widespread of having been carried to the four quarters of the globe by trade and travel. It is supposed to have originated in China in the Province of Yunnan on the Tibetan border, reaching Canton in 1894 and Calcutta and Bombay in 1896. In India, millions were swept away, the peak of mortality being reached in the four-year period from 1897 to 1908, when 4,325,237 deaths were attributed to this cause. In the succeeding years, the mortality rate in India gradually decreased to a low point in 1942, when there were 10,577 deaths. There was an increase during World War II to 41,700, with an abrupt fall in 1948 to 9,757 deaths attributed to plague. During this pandemic, plague spread to Singapore, the Philippine Islands, Arabia, Persia, Turkey, Egypt, West Africa, and later to Russia, parts of Europe, to the coast of North and South America, Central America, the West Indies, Mexico, and thence to the North American gulf coast. Nearly every country in the world was affected.

**ENDEMIC FOCI.** There are historic endemic foci where plague has slumbered for ages. Recently others have been disclosed. In central Asia on the eastern slopes of the Himalayas, and in northern China plague has been present for ages among the *tarbagans*. At present the most active endemic foci are in India and Burma. Plague is also endemic in other remote parts of Asia as well as on some of the near islands of which Ceylon, Java, and Madagascar have the greater commercial importance. In 1898, Koch discovered an endemic focus in Africa near the source of the White Nile in Uganda. Since then, foci have been discovered among wild rodents in South Africa, in the Mediterranean littoral of North Africa and in the Atlantic littoral of West Africa. In South America, there are endemic foci in Argentina, along the Atlantic Coast of Brazil, the Caribbean Coast of South America, in Peru, and Ecuador. Endemic foci entirely rural in character have been established on the islands of Maui and Hawaii in the Territory of Hawaii. More than 70 species of wild rodents have been found to be naturally infected.

In the United States, bubonic plague was first recognized in San Francisco in 1900. Up to February, 1904, when the city was declared free of plague, 121 cases with 113 deaths, principally in Chinese and Japanese confined to the Chinese quarters of the city, were officially acknowledged and reported. No further cases occurred with proven exposure within the city until May, 1907, a year after the great fire. The disease was widespread throughout the city, almost all cases being among white persons. Between May, 1907, and November, 1908, 159 cases with 77 deaths were reported. The discovery of plague in ground squirrels (sylvatic plague) followed, and since 1908 human plague has occurred principally as sporadic cases scattered through the western states and traced to contact with wild rodents.

In 1914, bubonic plague appeared in New Orleans. There were 30 cases and 15 deaths. In 1919, there were 12 cases in that city and in 1920, seven. In the latter year, the disease spread to adjacent communities and the Gulf States causing 11 cases in Texas and 10 in Florida. Since that time there have been no further cases of human plague traced to commensal rats in the United States.

**SYLVATIC OR CAMPESTRAL PLAGUE IN THE WESTERN U. S.** Annually, in widely separated sections of the western part of the United States, two or three species

cases of bubonic plague make their appearance. These human cases serve as indicators or signal posts of existing wild rodent enzootics or epizootics. In connection with these recurrences the operations of crews have gradually been extended to a wider and wider territory. Plague has been found by inoculation of pooled tissues from wild rodents or pools of fleas collected from them, into guinea pigs. These studies have demonstrated that infection is widely distributed among 13 western states (Meyer, 1942). The area now involved extends as far east as Kansas, New Mexico, Oklahoma, and Texas.

Until 1935, attention was largely restricted to the ground squirrel. During recent years, however, a great variety of animals has been investigated and infection has been found in 38 wild rodents, including not only 15 species of ground squirrels but kangaroo rats, marmots, meadow mice, wood rats, grasshopper mice, cotton tail rabbits and prairie dogs. Infected fleas have been taken from chipmunks, weasels, deer mice, harvest mice, cotton rats, and badgers.

The conditions which in the past have produced, and now maintain, these pockets of sylvatic disease are not clearly understood. They involve the ecology of the wild rodent and flea populations, the host relationships of *Pasteurella pestis*, and environmental factors. The theory that the infection originated with importation of rat plague into San Francisco by ships from the Orient at the turn of the century, and has gradually extended into the wild rodents of the western part of the United States has its supporters, while Meyer has maintained that sylvatic plague is far older than rat plague and it was probably enzootic on the American continent before its discovery in the west coast ports.

*Pasteurella pestis* (*Bacillus pestis*), discovered by Yersin during the Hong Kong epidemic of 1894, has more than fulfilled Koch's laws. Several accidents in which pure cultures have been introduced into man, producing all the symptoms and lesions of the disease, have added to the proof that this organism is the cause of plague. The bacillus is comparatively easy to isolate, grows readily on artificial culture media, and has characteristics that clearly distinguish it from all other species. In smears it usually appears as a short rod with rounded ends which show bipolar staining. There is a tendency to polymorphism, sometimes to the extent of round or coccoid forms. It is nonmotile, is decolorized by Gram's stain and grows well at room temperature.

Recognition of the bacillus rests upon the following characteristics: (1) Curious evolution forms upon salt agar within 24 hours; (2) stalactite growth in liquid media; (3) characteristic lesions produced by experimental plague in guinea pigs, rabbits, rats, etc. Kolle's method consists in rubbing the material containing the plague bacillus upon a shaved area of the skin of a guinea pig. The plague bacilli penetrate the skin, leaving other organisms behind. The skin of the guinea pig thus acts as a differential filter. (4) Finally, its pathogenicity may be neutralized by the use of antiplague serum.

*Pasteurella pestis* has no spore; its resistance corresponds about to that of the colon bacillus. It is readily killed by drying, sunlight, heat, and the usual germicides. In the feces of dead rats it may live for two months, in sputum from pneumonic cases 10 days, and under special circumstances from 6 to 15 days on fabrics and surfaces. There is, however, comparatively little danger of contracting the disease through fomites in real life.



**IMMUNITY.** One attack of plague usually protects for life. Occasionally, second attacks are noted in the same person, but they usually are mild. Artificial immunity of either an active or passive nature may be acquired by various procedures. The passive immunity induced by Yersin antiplague serum lasts only three weeks. *Yersin's serum* is obtained by immunizing horses with dead, then living culture. It has some therapeutic value when given early in the disease and a feeble, transient protective action. The active immunity produced by vaccination may last several months or longer. In India, plague workers are generally vaccinated once a year.

Vaccines may be prepared in several ways; even attenuated living cultures have been tried. The most widely used vaccine is *Haffkine's prophylactic* which is now prepared by growing the organisms for four weeks in bouillon at 25° to 30° C and then killing them at 55° C for 15 minutes. One half of 1 per cent of phenol is added. Two ml. of this vaccine is injected subcutaneously and in 10 days a second dose is given; sometimes after a week or more a third dose is injected.

From 1934 to 1941, Otten in the Dutch Indies, Pirie and Grasset in Johannesburg and Girard and Robic in Madagascar published observations based on the extensive use of vaccines made from living, avirulent cultures and interpreted the evidence as establishing the superiority of such preparations over dead cultures of *P. pestis* in protective value. However, an immunization procedure which gives a high degree of protection in experimental animals has been found to afford only a relative immunity for a short period of time in man. Some persons who were repeatedly vaccinated died of plague. Moreover, the reactions which follow vaccination with plague culture, whether alive or dead, are sometimes severe. The symptoms consist of a rise in temperature to 39° C, malaise, depression, and headache and swelling and pain at the site of the inoculation. The symptoms usually pass away in 24 to 48 hours. The recent studies of Meyer (1947) indicate that antigenic fractions of *P. pestis* can be prepared which when administered in serial doses induce a high level of antibody response in man with relatively mild local and systemic reactions.

**Plague Control.** The preventive measures necessary in controlling the two types of human plague are fundamentally different; thus, the primary pneumonic form or cases of secondary plague pneumonia demand strict isolation, as this form is one of the most highly contagious infections on the list. Doctors, nurses, ward tenders and others in close contact with cases run a special hazard. Bubonic plague is not directly communicable from man to man. Its control depends upon the eradication of the disease from among infected rodents. Human bubonic cases should be isolated in hospital wards, although contact infection is unlikely when ordinary care is used in handling such cases.

The sulfonamides have been shown to have curative effects in the treatment of plague. The antibiotics, chloramphenicol, aureomycin and streptomycin are effective against experimental bubonic or pneumonic infections in monkeys when therapy is instituted during the early phases of the disease (McCrumb and others, 1950). Contacts and suspected contacts of patients with pneumonic plague are first detected and segregated; temperatures are taken and chemoprophylaxis instituted. From three to eight grams of sulfadiazine should be administered each day for

seven days. The extent to which plague vaccine is to be employed on exposed contacts and on the general population must be decided locally.

In any community where plague first appears a general warning should be issued immediately regarding the danger of contact with sick and dying rodents and their fleas and the part played by them in the spread of the disease.

An active antiplague campaign demands a central head, under whose direction could be organized laboratory facilities for diagnosing plague in man and rodents; facilities for the detection of human cases; a department thoroughly versed in methods of suppressing rat and flea populations. Trapping rats is required not only for their destruction but also to determine the extent of the disease among them and location of infected foci. In order to reduce the rodent population to the point where plague will disappear it will be necessary actively to employ all the measures discussed under the heading of rodent control (see Section 1, Chapter 8).

Buildings in which there are human cases of plague and where infected rodents are discovered, and other structures and surroundings in the same locality demand immediate intensive treatment to kill rats and infected fleas in order to prevent secondary cases and to abolish an infected rodent focus.

The results of antiplague measures vary greatly in different parts of the world. In some cities the disease has been quickly conquered, while in others progress has been slow, and in some places there has been complete failure in eradicating rodent infection. A number of factors have influenced the results obtained by eradication measures.

1. The degree of rodent infestation with *Xenopsylla cheopis* has a decided influence on the rapidity with which plague spreads and the extent of rodent infection. The degree of flea infestation is largely determined by climatic conditions: rats living out of doors where there is excessive rainfall are relatively free of fleas compared to those in drier zones.

2. Suppressive measures should give quicker results in highly susceptible, urban communities where plague has existed for some time and the rodent population is more or less immune at the beginning of the epidemic.

3. The extent of rat infestation of a community, the type of building construction, and the sanitary education of the inhabitants have a decided bearing on the prevalence of plague and the difficulty of eradication. Ratproof construction tends to limit the degree of infection and renders active suppressive measures more certain.

4. The presence of plague among field rodents is a continual menace to nearby urban communities and complicates the eradication of the disease because of the great difficulty in controlling the far flung and wild endemic focus.

5. The presence of an active flea transmitter other than *Xenopsylla cheopis* makes eradication more difficult. *Xenopsylla hawaiiensis* found on field rats in the rural plague infected zones of the Hawaiian Islands is a flea of this class.

In the attempt to control plague in urban communities in the past, emphasis has been placed principally on suppression of the rat population. Obviously, a more rapid and direct approach is the suppression of the flea population. With the introduction of the use of DDT during World War II, this approach became practical. It was first used extensively by the United States military authorities in a control of plague at Dakar in 1944. The control methods used in this outbreak have been fully described by Gordon and Knies (1947). According to these authors, the modern



control of plague is based on the premise that the flea is the primary objective and that rats suffering from the disease or harboring fleas are of secondary importance. The principle of focal disinfection applies. The attack on the flea population should center about known infested areas, the house or building where a plague patient has been discovered. Having circumscribed an area within a radius of about 200 yards around the infected house, all persons and infestable things within that area should be disinfested, starting peripherally, working toward the central focus of infection. This is accomplished in respect to persons by dusting every individual in the area with a 10 per cent DDT powder. Pets and domestic animals are treated in the same way. Clothing, bedding, and furniture within the house are likewise dusted with DDT powder. Walls, ceilings and floors of houses, with especial attention to cracks, are treated with DDT residual sprays and oils. Rat harborages and runways are dusted with DDT insecticide powder. Rat-trapping lines are run radially beyond the focal zone. As plague-infected rats or new cases are detected, flea disinfection is extended, proceeding inward from the outermost point of suspected infection. In this manner, the area of focal disinfection is enlarged by extension to a general community basis. With the employment of such measures, it is anticipated that in the future plague will be more promptly and effectively controlled in an urban area.

*Personal prophylaxis* for those who must live in and visit infected regions consists in living and working in rat-free buildings. Haffkine's prophylactic vaccine is recommended for doctors, nurses, and others treating pneumonic cases. Other measures are evident from the context.

**MARITIME QUARANTINE.** Plague has been carried from one seaport to another by the transporting of infected rats on board vessels. Maritime quarantine, therefore, finds its greatest justification in keeping out plague. The universal adoption of measures for rat-proof construction of vessels and periodic rat infestation inspection with fumigation when necessary will greatly lessen the menace of plague introduction into clean ports. The measures used to prevent the ingress and egress of rats on infected and clean ports is discussed under the heading of the suppression of rats on vessels. The period of detention of personnel for a plague ship is seven days. It is comparatively easy to keep plague out of a seaport. Once in, it may require a long time, much ingenuity and considerable outlay to root out the infection.

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TULAREMIA

Tularemia is an infectious disease caused by *Bacterium tularense* [Synonym: *Streptococcus tularensis* (Bergey and others)]. Primarily, it is a fatal bacteremia of rodents, especially rabbits and hares; secondarily, an accidental infection of man. Tularemia is remarkable in that it occurs among a wide and extraordinary range of wild animals and is contracted by every known method of transmission: usually through wounds or insect bites; sometimes through the conjunctiva or the broken skin, and even by ingestion.

Table 6-3. Cases of tularemia reported in the United States

Year	Cases	Deaths
Previous to 1924 .....	15	2
1924, 1925, 1926 .....	308	11
1927 .....	251	10
1928 .....	350	10
1929 .....	462	36
1930 .....	659	37
1931 .....	675	32
1932 .....	933	41
TOTAL *	3653	179

\* Case fatality 4.9 per cent.

**History and Synonyms.** McCoy first described the disease in 1911 as a "plague-like disease of rodents" in California, Tulare County; hence the name tularense. McCoy and Chapin in 1912 discovered the causative organism, *Bacterium tularense*. Martin, an ophthalmologist of Arizona, called attention in 1907 by correspondence to five human cases occurring in his practice caused by skinning jack rabbits. Pearce of Utah, in 1911, described six human cases under the heading of "insect bites." Gil, Wherry, and Lamb of Cincinnati, in 1914, described a human case as "*Bacillus tularense* infection of the eye." Francis, in 1919 and 1920, described "deer fly fever" of Utah, recognized its identity with McCoy's "plague-like disease of rodents" and named the disease "tularemia."

**Geographic Distribution.** Human cases have been reported from 48 states of the United States and from the District of Columbia. During the 22 years from 1924 to 1945, before the discovery of streptomycin, the number of cases of tularemia reported by state health officers to the U. S. Public Health Service was 19,208 and the number of deaths recorded by the U. S. Office of Vital Statistics was 1,432, giving a mortality of 7.4 per cent which included all types of tularemia. The disease has been reported in Japan in 1925, in Russia in 1928, in Norway in 1929, in Canada in 1930, and in Sweden in 1931. With increasing knowledge the area is widening.

**Zoologic Distribution in Nature.** *Bacterium tularense* has been isolated from naturally infected animals as follows: wild rabbits and hares and their ticks, widespread in the United States; California ground squirrels, often; ground squirrels of Utah, wild rats of Los Angeles, wild mice of California, quail, ruffed grouse, sharp-shinned grouse, and gray foxes of Minnesota, once each; sage hens and their ticks in Montana, once; sheep of Idaho, three times; wild rabbits of Japan, Norway, and



Canada; the water rat of Europe (Russia); wood ticks of Montana and Minnesota, often; and wood ticks of California, once.

**Transmission among Wild Animals.** Bloodsucking insects (ticks, lice, flies, and perhaps fleas) are believed to transmit the infection from animal to animal in nature. Domestic rabbits are just as susceptible as wild rabbits but have never been found naturally infected, probably on account of the lack of transmitting insects.

**Susceptibility.** It is noteworthy that domestic animals are largely resistant. Many rodents are susceptible. Various degrees of susceptibility are noted: highly susceptible (man, monkey, ground squirrel, rabbit, guinea pig, mouse, groundhog, muskrat, beaver, ferret, weasel, cotton rat, water rat of Europe, prairie dog, chipmunk, pocket gopher, and porcupine); slightly susceptible (cat, sheep, goat, white rat, wild rat (*norvegicus*), coyote, opossum, quail, Hungarian partridge, sage hen, ruffed grouse, sharp-tailed grouse, wild fox, and mallard duck); not susceptible (horse, cattle, hog, dog, chicken, pigeon, turkey, ringnecked pheasant, hawk, badger, and skunk).

**Clinical Types.** There are four clinical types of the disease: (1) *ulceroglandular type*, in which the primary lesion is a papule of the skin, later an ulcer, accompanied by enlargement of the regional lymph glands. Subcutaneous nodules appear between ulcer and regional lymph nodes. In the pulmonary form there is pleurisy with effusion. There is also a meningeal form. (2) In the *oculoglandular type* the primary lesion is a conjunctivitis accompanied by enlargement of the regional lymph glands. (3) In the *glandular type* there is no primary lesion at the site of infection, but there is enlargement of the regional lymph glands. (4) In the *typhoid type* there is no primary lesion, nor is there glandular enlargement. (The word "typhoid" is used here in the sense of an absence of manifest external lesions and not as signifying the so-called typhoid state of mind.)

**Sources of Human Infection.** A large number of cases of tularemia have been studied with reference to type and source of infection.

1. *Ulceroglandular type*, 1,328 cases: *fly bite* (*Chrysops discalis*), 34 cases in Utah, Montana, Wyoming, Idaho, Oregon, Colorado and Nevada; *tick bite* (*Dermacentor andersoni*), 37 cases in Montana, Wyoming, Idaho, North Dakota, South Dakota, Nevada and California; *tick bite* (*Dermacentor variabilis*), 58 cases in Arkansas, Texas, Louisiana, Missouri, Kansas, Illinois, Tennessee, Georgia, North Carolina, Virginia and Minnesota; *insect bite* (species ?), 9 cases in California, Colorado, Nevada, Michigan, Louisiana and Texas; *sheep contact* and consequent contact with wood ticks and their feces as in shearing, herding and butchering, 7 cases in Montana, Wyoming, Nevada and Idaho; *wild rabbits* shot and dressed, 163 cases; bought or sold in markets, 169 cases; dressed or skinned or cut up for dog feed, hog feed, chicken feed, fox feed, fish bait or trap bait, 807 cases; *water rats* of Europe (*Arvicola amphibius*), killed and skinned for their pelts in Russia, about 1,000 cases; occasional cases from skinning and dressing tree squirrels, quail, sage hens, opossums, deer, ground-hogs, muskrats, skunks, coyotes, a wild fox, hog, a bull snake; an occasional case from bite or scratch of dogs, cats, skunks, coyotes, tree squirrels, Montana ground-squirrels, opossums, dog, hog, lamb or white rat, contamination of mouth parts or paws being assumed. The list is impressive.

2. *Oculoglandular type*, 64 cases: *wild rabbits* skinned or dressed, 40 cases; a fly crushed between the fingers, 1 case; ticks pulled from a horse, cow or dog 4

shed between the fingers, 10 cases; *rabbit blood* or bloody water spurted into the eye, 2 cases; *bile* from a ruptured gallbladder of a ground-hog spurted into the eye, 1 case.

3. *Glandular type*, 29 cases: *wild rabbits* dressed, 24 cases; *tick bite*, 1 case; *ingestion* of insufficiently cooked wild rabbit, 3 cases; *experimental human infection* on back of hand, 1 case.

4. *Typhoid type*, 55 cases: *laboratory workers* who autopsied infected guinea pigs, rabbits, or white mice or handled infected living ticks, 37 cases; *wild rabbits* dressed, 10 cases; *tick bite*, 4 cases; ingestion of insufficiently cooked wild rabbit, 1 case; an *opossum* skinned, 1 case.

**Symptoms.** The incubation period is from 1 to 10 days, the average being about three and one-half days. The onset is sudden with headache, chills, body aches, vomiting and fever. The primary lesion, whether on the skin or in the conjunctival sac, usually proceeds to ulceration and quickly gives rise to inflammation of the regional lymph nodes which suppurate in about half of the cases.

The fever lasts two or three weeks and may reach 104° F with a transient remission on the third or fourth day, or daily remissions suggesting a septic type of fever. Convalescence is slow and drags along with weakness for several months, sometimes longer. Some cases are ambulant throughout. Skin eruption and subcutaneous nodules are noted in some cases. Recovery usually occurs without sequelae. Pleural effusion is not rare. Symptoms suggesting pneumonia constitute a grave prognostic sign. Death occurs in about 5 per cent of cases.

**Diagnosis.** The history of the case and the symptoms may suggest tularemia but diagnosis depends upon agglutinins or cultures of *Bacterium tularense*. Specific agglutinins appear in the blood at some time in the second week and remain for a long time—even several years. Material from the site of infection or from the enlarged glands inoculated into guinea pigs causes their death within a week with enlargement of the regional lymph glands and small areas of focal necrosis studded in the liver and spleen from which *Bacterium tularense* can be recovered in pure culture on coagulated egg yolk or blood-dextrose-cystine agar. Cross agglutination with *Brucella abortus* by the blood serum is rather common and may rarely necessitate a precipitin absorption test if *abortus* and *tularense* are agglutinated out to the same solution of serum.

*Bacterium tularense* is a small organism occurring regularly in coccoidal and bacillary forms and very rarely bipolar; it is Gram negative, aerobic, without spores, nonmotile; it grows on coagulated egg yolk or blood-dextrose-cystine agar, but not on plain agar. In smears, it stains well with crystal violet and in sections it stains with Giemsa solution. In three of eight attempts it passed through Berkefeld filters which held back a small staphylococcus.

The organism is killed at 56° to 58° C in 10 minutes. Formaldehyde solution, alcohol and the usual germicides are effective. In bedbug feces the virus resisted boiling for 25 days.

**Cultures** on blood-dextrose-cystine agar, kept at room temperature, require monthly transfer and quickly lose virulence, but cultures kept between 12° C and 15° C and transferred every two months retain their virulence about five years. Annual transfer of cultures is sufficient to keep them viable and virulent.

*Refrigerated carcasses* of infected rabbits stored at 3° C showed survival of



virulent organisms in spleen for one month, in muscle of thigh four months, in brain four months and in spinal cord five months. Carcasses stored continuously without thawing at  $-15^{\circ}\text{C}$  showed survival of virulent tularensis organisms in bone marrow of femur 10 months, in liver 11 months, in muscle of thigh 12 months, in spleen 19 months, and in brain and spinal cord two years.

**FREEZING AND THAWING.** Rabbit livers and spleens which were stored frozen at  $-15^{\circ}\text{C}$  during each night but allowed to thaw at  $20^{\circ}\text{C}$  during each intervening day were free from virulent infection at the end of seven days of such alternate freezing and thawing.

*Glycerinated spleens* of infected guinea pigs (spleens placed entire in pure undiluted neutral glycerin) showed survival of virulent organisms for one month at room temperature, six months at  $12^{\circ}\text{C}$ , two years at  $3^{\circ}\text{C}$  and six and a half years at  $-15^{\circ}\text{C}$ . The naked bacilli suspended in pure glycerin and stored at  $-15^{\circ}\text{C}$  were virulent for two years and nine months.

**Modes of Transmission.** **INSECT TRANSMISSION.** Transmission from rabbit to rabbit in nature is by the rabbit tick *Haemaphysalis leporis-palustris* Packard, the rabbit louse *Haemodipsus ventricosus*, the wood tick *Dermacentor andersoni* and the dog tick *Dermacentor variabilis*, which keep the infection alive in rabbits throughout the year.

Insect transmission to man is (1) by the wood tick *Dermacentor andersoni* Stiles; (2) by the dog tick *Dermacentor variabilis*; and (3) by the bloodsucking fly *Chrysops discalis* (deer fly).

**TICK INFECTIONS.** *Dermacentor andersoni* is commonly found in Montana and the surrounding states. It feeds on rabbits, domestic animals, and man, and is active during March, April, May, and June. When feeding, it attaches beneath the clothing or in the hair, remaining attached for days, during which time infection takes place by the introduction of its feces into the biting wound. This tick harbors the infection in its coelomic fluid, in the epithelial cells of its rectal sac and gut and in its feces. The virus is capable not only of surviving the winter in this tick and of being transmitted from stage to stage as the tick develops, but it is transmitted through the egg to the next generation of ticks. The mere handling of a tick may cause infection. *Dermacentor variabilis* is found commonly in the southern states. It feeds on rabbits, dogs, and man, and has caused cases in all months of the year except November, December, and January. It attaches beneath the clothing or in the hair.

**FLY INFECTIONS.** The horsefly *Chrysops discalis* is commonly found on horses and cows in Utah and the adjoining states during the months of May, June, and July. This fly, after biting an infected rabbit, bites man on an exposed part of the body—face, ears, or neck. In contrast to the tick, the fly remains infected not over 14 days and it feeds several times a day but only for a few minutes at a time. Transmission is purely mechanical, due to contamination of its mouth parts.

**CUTANEOUS WOUND INFECTIONS.** In the majority of human cases a wound entry has been inflicted at the site of cutaneous infection either at the time of infection or shortly before or after. These wounds consist of cuts, punctures or scratches by fragments of shot-shattered rabbit bone or by knife, nail, barbed wire, thorn, briar or burr or splinter of wood, etc. In the fly-bitten, tick-bitten and animal bite cases the bite constitutes the wound. Cutaneous inoculation, *i.e.*, rubbing infectious material on the abraded skin of the abdomen of a guinea pig, is the routine method.

propagation of a strain of tularemia in the laboratory. This method also serves to "sterilize" a pure culture from grossly contaminated tissue.

**PENETRATION OF UNBROKEN SKIN.** Evidence that *Bacterium tularense* can penetrate the normal skin is as follows: (1) Ohara gently rubbed the back of a hand with the heart and blood of a wild rabbit found dead, thus causing a typical case of tularemia confirmed by the agglutination test and by characteristic cellular pathology in the regional lymph nodes of the axilla but there was not any lesion on the hand. (2) Laboratory infection of 37 workers did not cause any lesions of the hands nor lymph node enlargements. One of these had derived his infection through a prick of his finger with a thumb tack which held an infected guinea pig on the board. (3) Dressing of wild rabbits in 24 cases resulted in absence of lesion on the hands with enlargement of regional lymph nodes. (4) Rabbits and guinea pigs become infected regularly in the laboratory by the gentle application of a culture to their normal skin between the shoulders but without abrading, rubbing, shaving or clipping. In the last analysis, no one really knows at the present moment whether he has a small abrasion of the skin of his hands, much less does he know what the condition was three or four days ago.

**LABORATORY INFECTIONS.** In 11 laboratories the disease has been contracted by 17 workers, who had either (1) performed or assisted at necropsies of infected guinea pigs, rabbits or white mice, or (2) had held infected living rabbits or guinea pigs, or (3) had handled infected living ticks. In these cases the infection enters through the skin of the hands, presumably the unbroken skin.

**MARKET INFECTIONS.** During the months of November, December and January which embrace the "open season" for wild rabbits these rodents are shot, shipped long distances, and offered for sale in the markets in large numbers. Of a total of 100 rabbit livers examined in the Washington, D. C., market, nine, or slightly more than 1 per cent, were found to contain virulent *Bacterium tularense*. Twenty-two human cases of tularemia were traced to rabbits sold in that market and dressed by market men, cooks or housewives. A serological examination for antitularense agglutinins in the rabbit dressers in the market should furnish a quick and reliable answer as to the prevalence of tularemia in rabbits.

**EYE INFECTIONS.** The conjunctiva is more susceptible than the skin as shown by 53 cases having the primary seat of infection in the conjunctival sac without evidence of a simultaneous lesion on the hands which conveyed the infection to the eyes.

**INGESTION.** Insufficiently cooked rabbit meat caused three serious outbreaks. The marrow of infected rabbits is known to be studded with lesions rich in organisms, which, in conjunction with red juice around the bones and mass ingestion of meat, results in fulminating infection of man which may terminate fatally in only a few days. Laboratory animals are very susceptible to infection by ingestion of food which has been artificially contaminated with infected animal tissue. White mice regularly become infected after eating infected bedbugs. Mice become infected by eating infected mice.

In 1935 an explosive water-borne epidemic of tularemia in the U.S.S.R., was reported by Karpoff and Antonoff. Over 43 cases were observed in a group of farm workers who used water from one stream which was found to be contaminated with *Bacterium tularense*. The portal of entry of infection appeared to be the tonsils and buccal



mucosa and in some instances the conjunctiva (Karpoff and Antonoff, 1936). In the United States since 1942, contamination of numerous streams in Montana at one time or another, often persisting for months, has been repeatedly demonstrated at the Rocky Mountain spotted fever laboratory (Jellison and others, 1942; Parke and others, 1943). In most instances the presence of the organism in water has been associated with tularemia in beavers and muskrats inhabiting the streams or ponds concerned. Many cases of tularemia were contracted by persons who skinned or handled such diseased animals, but up to 1950 there was little evidence of human infection resulting from direct contact with contaminated water. In that year, Jellison and others (1950) reported the occurrence of four cases of tularemia associated with one domestic water supply under circumstances which appeared to exclude other likely sources of infection. *B. tularensis* was recovered from samples of the suspected domestic water supply upon two occasions. Four of the individuals who consumed water from this particular supply experienced a typical clinical illness with tularemia, with the primary infection in the tonsils and buccal mucosa.

**NASAL SECRETIONS, URINE AND FECES.** Rabbit urine, rabbit nasal secretions and mouse urine cause tularemia by subcutaneous injections, but not by feeding. Tick feces and bedbug feces are very infectious by inoculation into guinea pigs.

**COMMERCIAL DEMAND FOR PELTS.** Water rats of Russia were an unsuspected host of tularemia until the commercial demand for their pelts suddenly opened the avenue of infection, resulting immediately in about 1,000 cases. No human case of the disease has ever been traced to the California ground squirrel which was its first recognized host, but such cases may be only awaiting a commercial demand for those squirrel skins. Furriers, tanners, and jobbers in rabbit skins have not become infected owing to the lack of contact of their hands with the raw flesh and blood of wild rabbits.

**Immunity.** One attack confers permanent immunity in man, there being no record of a second attack. The highly susceptible laboratory animals (guinea pigs, rabbits, and white mice) practically all die when exposed to cultures of maximum virulence, the only exception being the rare rabbit which survives the injection of a series of cultures of increasing virulence.

**Prevention.** Although the disease is preventable, the number of reported cases in the United States is showing a slight yearly increase. Measures for personal protection are at the command of everyone. *Rubber gloves* furnish complete protection to the hunter, marketman, cook, housewife, laboratory worker and to the trapper and skinner of game. *Mental alertness* to the danger will help in avoiding the bite of insects and will forestall the deliberate handling or squashing of bloodsucking ticks, flies or their feces. *Disinfection* of bites, cuts, punctures, and scratches should be practiced, but the measure has often failed especially where the puncture was made by a sharp spicule of shot-shattered, marrow-smeared rabbit bone. *Disinfection* of ulcers, abscesses, sputum, conjunctival secretion, urine, and feces would be suggested but no case has been traced to those sources. *Thorough cooking* of wild game, especially rabbits and hares, not allowing any red juice to remain about the bones, is essential. *Immunes* should be employed for all work involving contact with the animal and insect hosts of the disease. A warning to the poor sportsman is necessary: he should not shoot the rabbit which is on the point of his gun, nor take a rabbit found dead, nor one which a cat or dog has brought in, nor the one which

oy has killed with a club. *Refrigeration* of wild rabbits with a view to rendering n safe by prolonged cold storage is economically unprofitable because of the g life (two years) of the organism in their tissues at  $-15^{\circ}\text{C}$ . *Isolation*, quaran- and house disinfection are not indicated. *Market inspection* of wild rabbits is racticable because the spotted spleens and livers have usually been discarded in ssing before arrival at market and because infected rabbits may be shot and keted before the small lesions, though present, attain macroscopic size. *Repeal* ne game laws which protect rabbits, and discontinuance of the practice of restock- the rabbit population would result in their immediate extermination from the ly agricultural states, but jack rabbits would still remain a pest west of the sissippi River.

Since the discovery of streptomycin by Waksman and the publication by Heilman others of its bactericidal effects on tularemia in laboratory animals, cases of remia in man treated by that antibiotic have been reported in the literature shay, 1947). Reviewing this evidence Francis (1947) concludes that this anti- ic is remarkably effective in bringing about prompt clinical recovery and in ncing the survival of *B. tularensis* in the human body from a prospective long term ve months' duration to a five-day period. There is evidence also that aureomycin hloramphenicol (chloromycetin) are effective in the treatment of the human ase (Parker and others, 1950).

The development of a vaccine which would be satisfactory in prophylaxis has ived considerable attention from investigators in recent years. A method which ld afford a high degree of protection without undesirable local and constitutional tions has yet to be devised. Recent reports, however, are encouraging (Kadull others, 1950).

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#### RELAPSING FEVER

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Relapsing fever comprises a group of specific infections caused by spirochetes e blood, characterized by relapsing attacks of fever lasting about a week and rring at like intervals. These spirochetes are placed in a genus designated as *Borrelia* or *Borrelia*, and the several species differ from one another in their



staining reactions, pathogenicity, and transmissibility by the species of ticks and lice which serve as vectors. A number of species have been described from various soft ticks and animal hosts; some of those which infect man are *B. duttoni* from Africa, *B. persica* from the Middle East, *B. berbera* from North Africa, *B. venezuelensis* from the neotropical region, and *B. turicatae* and *B. hermsi* from North America. The epidemic, louse-borne relapsing fever is caused by *B. recurrentis*.

Clinically, the relapsing fevers resemble one another, except that some are more virulent than others. The disease is characterized by sudden onset, intense frontal headache, and pains in back and limbs. The fever continues from three to five days and falls by crisis. The temperature remains normal for about a week, when the fever repeats itself. There may be 4, 5 or even 10 such relapses. The spirochetes are found in the peripheral blood only during the febrile period.

Obermeier in 1868 discovered the "spirillum" of epidemic European relapsing fever in the blood. Carter and Koch in 1878 showed that the infection may be transferred to apes by the inoculation of the blood of a patient. Munch and Moczutkowski transferred the disease by the inoculation of relapsing fever blood to healthy individuals.

**Louse-borne.** Epidemiologically, the disease exists in two forms, louse-borne and tick-borne. The former occurs in epidemics, and is dependent upon conditions which permit the building up of louse populations to the point where these insects are capable of acting as vectors of the spirochetes directly from man to man. It thus may co-exist with epidemic typhus. Such epidemics have occurred principally in Europe, Asia, and India; they occurred in New York and Philadelphia in 1869, but this type of the disease no longer exists in the United States. After the louse has imbibed a meal of infected blood, the spirochetes penetrate the gut wall and enter the insect's haemocoel. Most of the organisms are killed in the gut of the louse, and as only a few successfully penetrate the gut wall, they can not be found in the blood or tissues of the louse until several days have elapsed. During this time they apparently multiply by transverse division; older ideas that they passed through a granular stage are no longer tenable. They become numerous enough to be demonstrable microscopically after about a week. The spirochetes in the haemocoel are in a blind alley; they can not be transmitted by the bite or feces of the insect. When the louse is crushed, the skin or mucous membranes of the host are contaminated with the spirochete-laden blood of the louse, and the organisms gain entrance into the body through the skin scarified by scratching, or through the intact mucous membrane or conjunctiva.

**Tick-borne.** Tick-borne relapsing fever depends upon the habits of the tick and the tick hosts for its transmission. Dutton and Todd and also Koch, in 1903, showed that in Africa the tick, *Ornithodoros moubata*, was capable of transmitting the spirochetes. In the tick the spirochetes penetrate the stomach wall and enter the haemocoel. From here they invade the various tissues, including the salivary glands, the coxal glands, the Malpighian tubules, and the ovaries. Transmission to the vertebrate host may thus be effected by the injection of salivary secretion during feeding, by the coxal fluid which is excreted by some ticks while feeding, and by contaminated feces. In the ovaries, the spirochetes penetrate the eggs and hence are transmitted hereditarily from mother to offspring. Hereditary transmission may continue for several

rations without the reinfection of the tick by feeding upon infected blood; the tick thus acts as a reservoir as well as a vector.

In Africa, *O. moubata* and *O. savignyi* live in and about human habitations. They thus are responsible for direct transmission of spirochetosis from man to man, and may maintain a high endemicity. Koch observed natural infection rates in *O. moubata* as high as 50 per cent. The African natives had associated relapsing fever with *O. moubata* long before the scientific proof of the role of the tick as a vector was obtained.

*O. tholozani* are distributed from the Mediterranean region to central Asia. They are found in animal burrows, caves, rock shelters, and the like, where they feed upon rodents. People invading such haunts may be bitten by these ticks and contract relapsing fever.

*O. erraticus* live in rodent burrows in Africa and the Middle East and may occasionally transmit relapsing fever to man.

In Central and South America, *O. rudis* live in houses and thus can transmit the parasites from man to man or from rodents to man. *O. talaje*, which are found in Kansas and California to Argentina, seldom, if ever, feed upon man but probably are important in maintaining a reservoir of infection among rodents. However, it is not known whether spirochetes from *O. talaje* are transmissible by *O. rudis*. In western North America, *O. turicata* are found in caves and animal burrows; sporadic cases of relapsing fever occur among persons who enter the tick's habitat. *B. hermsi* live in nests of various wild rodents in the Rocky Mountain region. Hunters living in mountain cabins may be bitten and infected by these ticks when they wander from nests built beneath or in the cabin. Another species in the Rocky Mountain area, *O. parkeri*, seldom feeds upon man, but it also lives in burrows and nests and hence may be of importance in maintaining a reservoir of infection among wild rodent hosts.

**Extrahuman Survival.** No animal reservoir has been found for the louse-borne relapsing fever, but some workers doubt that man can be the reservoir. Lice are not; there is no hereditary survival of the spirochetes in these insects; furthermore, as the spirochetes cannot leave the louse unless the insect is crushed, transmission to only one person is possible by a single louse. The possibility exists that there is an animal reservoir for *B. recurrentis*, with an associated tick vector, and that louse-borne epidemics may originate under favorable circumstances from sporadic infections in man caused by ticks. Final proof is still lacking. Baltazard and his associates present evidence indicating that passage of *B. recurrentis* through rodents causes a transformation toward the characteristics of the tick-borne spirochetes. However, attempts to transmit the tick-borne spirochetes through lice have not been especially successful; also, the tick-borne spirochetes usually show a high specificity for certain tick species. Heisch, who points out that the tick-borne *B. duttoni* of Africa is not transmitted by lice, states that it is a mystery why epidemics of louse-borne *B. duttoni* do not occur.

There are conflicting reports regarding the efficacy of the arsenicals in the treatment of the disease; these discrepancies may be reconciled in part by taking into account the differences between strains or species of spirochetes and the development of arsenic-resistant strains.



More recently satisfactory results have been reported following administration of penicillin.

Recent discussions on the treatment of relapsing fever are those of Bergeret and Raoult (1948); Davis (1948); and Magee (1942).

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### THE TYPHUS GROUP

Typhus fever is undoubtedly one of the oldest pestilential diseases of mankind. Called by many names and confused with other fevers, it is not until the sixteenth-century writings that it can be certainly recognized as causing devastating epidemics. With plague, smallpox, typhoid and dysentery, it was a scourge of armies and civilian populations throughout the Middle Ages; it frequently played a decisive role in wars. The manner in which the course of the history of Europe was affected by these pestilences has been graphically portrayed by Zinsser in his "Rats, Lice and History," which every student of military medicine should read. The appellation "typhus" originated with Sauvages in 1760 and was derived from the Greek *typhos*, literally meaning smoke. Hippocrates used this word to describe a "confused state of the intellect; a tendency to stupor." Originally, typhus designated the self-limiting continued fevers which were characterized by stupor. In 1829, the French clinician, Louis, clearly differentiated typhus fever from typhoid fever. In the United States, attention was called to this differentiation in 1837 by W. W. Gerhard of Philadelphia, who had studied under Louis; and since then typhus fever has been recognized as a contagious disease characterized by sudden onset with high fever, severe headache, generalized maculopapular eruption, and termination by rapid lysis in about two weeks, or by a fatal issue.

About the turn of the century, there began to appear in the medical literature from various parts of the world descriptions of fevers which resembled typhus but differed from it in clinical course or mode of occurrence. These typhus-like fevers were gradually differentiated in their etiology, pathology and epidemiology. Classified according to their arthropod vector, the four principal diseases in the typhus group are: (1) louse-borne, or epidemic typhus; (2) flea-borne, or murine typhus; (3) tick-borne, particularly Rocky Mountain spotted fever; (4) mite-borne, or scrub typhus (tsutsugamushi disease).

Further investigations established the fact that these diseases were caused by micro-organisms intermediate in character between bacteria and viruses and called rickettsiae. They are small pleomorphic coccobacillary organisms which are visible

microscopic preparations with Giemsa or Macchiavello stain and which cannot be grown on artificial media. They multiply only in certain cells of susceptible arthropods and vertebrate hosts and of chick embryos. As their natural history has developed, it appears that they are primarily parasites of arthropods. The human diseases which they cause are sometimes designated "rickettsioses." These include not only the typhus-like fevers but also three other human diseases which have been differentiated; namely, trench fever, Q fever, and rickettsialpox.

### EPIDEMIC TYPHUS FEVER

(*Typhus Exanthematicus*, *Classic or European Typhus*)

Typhus fever is an acute specific infection caused by *Rickettsia prowazeki*. The period of incubation is from 6 to 15 days, commonly about 12 days. The onset is more or less sudden with chills, fever, and severe headache. Between the fourth and seventh days a maculopapular rash appears and becomes generally distributed over the body. At first the spots are erythematous in character disappearing on pressure, but after the second day become persistent and often converted into true chancres. There is an early and great prostration, with heavy flushed countenance and injected conjunctivae. Nervousness, mental dullness, and insomnia may be followed at the end of the first week by delirium. In the very severe cases this develops into stupor and coma. Duration of the fever is from 10 to 21 days, usually 14 days, terminated by rapid lysis. Convalescence may be characterized by weakness and depression. According to Murchison, the case fatality rate, based upon 18,268 admissions in London Fever Hospital, 1848 to 1870, was 19 per cent. The case fatality was about 3 to 4 per cent in childhood and rose steadily with advancing age, so that more than 50 per cent of the cases in old people terminated fatally. Today, with good medical care and early judicious administration of such antibiotics as streptomycin or aureomycin, the risk of a fatal issue can be greatly decreased.

The clinical manifestations are due to the ability of the rickettsiae to multiply within the endothelial cells lining the small blood vessels. Vascular lesions having a necrotic histologic appearance sometimes referred to as Fraenkel's nodules are not numerous in the skin, central nervous system, and myocardium, but are found scattered widely throughout the organs of the body.

**Laboratory Diagnosis.** The clinical course of the disease and the characteristics of the eruption are sufficiently distinctive to permit clinical diagnosis. Serological confirmation is sought through employment of the Weil-Felix test or the complement-fixation reaction.

The investigations of Weil and Felix in 1916 and of Felix (1944) and others, have established the fact that patients sick with typhus fever develop agglutinins for certain strains of *Proteus*, namely, X19 and X2. X19 has been found to be the most sensitive indicator and suspensions made from the nonmotile O variant the most specific. Agglutinins for OX19 and OX2 appear in the sera of most typhus patients between the fifth and eighth day of the illness. In more than 90 per cent of cases the titer for OX19 rises to 1:160 or higher, sometimes reaching a titer of 1:2,560 or more. Diagnostic significance is attached to a rise to 1:160 or greater. Rarely, individuals are encountered whose serum agglutinates *Proteus* OX19 although they do not have typhus fever. The peak of the response usually occurs about the time



of early convalescence; thereafter, it declines rather rapidly and in most instances below significant levels within three months after onset. No etiologic relationship has been demonstrated between these strains of *Proteus* and typhus fever. Castaneda, in 1934, demonstrated a carbohydrate antigen common to OX19 and *R. prowazeki*. The reaction is, therefore, empiric, but none the less a very useful one because of its simplicity.

The discovery by Cox (1938) that *R. prowazeki* could be grown in the yolk sac of developing chick embryos, made it possible to prepare large amounts of antigen for serologic tests. Complement-fixing antibodies appear in the sera of patients as early as the fifth to seventh day of illness. They increase in titer, reaching a peak in the first two or three weeks of convalescence. Thereafter, the titer falls slowly over a period of several months to low values, which may persist for years. Plotz and others (1943) described a method for the preparation of purified complement-fixing antigens from infected yolk sacs which would permit differentiation between epidemic and murine typhus. This differentiation, however, depends upon carefully standardized antigens and is not routinely available in diagnostic laboratories. It is now also possible to test sera of suspected cases of typhus for specific agglutination with suspensions of rickettsia. The time of appearance of these antibodies is approximately the same as for complement-fixing antibodies.

**Inoculation of Experimental Animals.** Monkeys, guinea pigs, rats, rabbits and other rodents are susceptible to experimental infection with *R. prowazeki*. Because of ease of handling and characteristic reaction, the guinea pig is the animal of choice in most experimental work. The infection may be established in guinea pigs by the intraperitoneal inoculation of blood taken from a typhus patient early in the febrile period. It is advisable to allow the blood to clot and to separate the serum for use in serologic tests. The clot is then ground with equal volume of sterile saline skimmed milk or nutrient broth. After allowing the suspension to stand until large particles have settled out, 4 or 5 ml. are injected intraperitoneally into a male guinea pig weighing at least 500 gm. Rectal temperatures are taken daily. After an incubation period varying from one to three weeks, a definite rise in temperature to 40° C or more indicates a probable infection. The temperature remains elevated for a few days and then returns to normal. To propagate the infection, blood is obtained by intracardial puncture or by killing the animal on the third or fourth day of fever and removing the brain and spleen. One of these organs is emulsified with normal saline and 1 to 2 ml. of suspension used for intraperitoneal inoculation of guinea pigs for the next passage. Guinea pigs survive typhus infection unless the infective dose is massive. Ordinarily, there is no visible scrotal reaction; strains of epidemic louse borne do not exhibit the Neil-Mooser reaction (Mooser, 1928). The infected guinea pig does not develop a positive Weil-Felix reaction. Both the white rat and wild rat can be experimentally infected. In these animals the infection is inapparent but they develop antibodies which can be demonstrated by the complement-fixation test.

**Transmission by Lice.** Transmission of typhus by the louse (*Pediculus humanus humanus*) was first demonstrated experimentally by Nicolle and others (1909). Their observations were confirmed by Ricketts and Wilder in 1910 and Anderson and Goldberger in 1912, and others.

This was the starting point of a series of investigations during World War I by von Prowazek; da Rocha-Lima; Otto and Dietrich; Nicolle; and by Wolbach and

iates (1922), and others, which revealed the essential biologic relationships between human typhus and to the causative agent, *R. prowazeki*, named in honor of Ricketts and von Prowazek, who as a consequence of their researches contracted the disease and died.

When lice are fed upon a typhus patient during the febrile period of the illness, a large proportion become infected with *R. prowazeki*. The organisms enter the cells lining the intestinal tract of the louse where they multiply. The parasitized cells are shed and the organism may then be passed in the feces of the louse or may enter the cells lining the intestinal tract. Rickettsiae appear in the feces of typhus-infected lice about three to five days after the first infective meal. Rickettsiae have been demonstrated in louse tissues, such as the salivary glands. The louse usually succumbs to the infection after 7 to 10 days. The course of typhus infection in human head louse *Pediculus humanus capitis* is the same as that in the body louse *Pediculus humanus corporis*. The latter is far more important in epidemic transmission.

Apparently the infection is transmitted to human beings by fecal contamination of a wound made by the louse in feeding or made by the host in scratching. In the feces, rickettsiae may survive for years under experimental conditions if temperature and humidity are kept low. Since the clothes of patients are frequently contaminated heavily with louse feces, it has been suggested that infection is occasionally transmitted by the air-borne route to the respiratory tract of a susceptible person. That it is possible to infect human beings by the respiratory route has been proved by laboratory experience. Several instances are on record where laboratory workers have acquired typhus as a result of laboratory accidents in which material containing rickettsiae was dispersed into the air by a Waring Blendor or by the bite of a mouse during the procedure of intranasal instillation. But while air-borne transmission is theoretically possible, it is relatively unimportant under conditions of actual exposure (Davis, 1947). The common mode of transmission without doubt is the inoculation of a louse bite with louse feces containing rickettsiae.

**Epidemic Propagation.** The elucidation of the role of the louse in transmission defined the epidemiology of typhus. Propagation is maintained in human populations by the circulation of lice from person to person. The louse is a relatively inefficient vector, since it has a very short range of movement; it crawls and does not fly. It must reach a susceptible noninfected human being within two weeks after an infective feed to be successful in transmission. There is no generation to generation transfer of *R. prowazeki* through the egg. It follows that epidemic spread is maintained by the existence of a large louse population on human beings who are crowded together in their living or sleeping quarters. Whether the louse or the human being is to be regarded as the source of the infection depends upon point of view. The situation is humorously depicted by Zinsser in his "Rats, Lice, and History" as follows: "The louse shares with us the misfortune of being prey to the typhus virus. We can dread, the nightmare of their lives is the fear of some day inhabiting an infected . . . human being. For the host may survive; but the ill-starred louse that has his haustellum through an infected skin, and imbibes the loathsome virus with his nourishment, is doomed beyond succor. In eight days he sickens, in ten days he is *in extremis*, on the eleventh or twelfth his tiny body turns red with blood, he is evacuated from his bowel, and he gives up his little ghost. Man is too prone to



look on all nature through egocentric eyes. To the louse, we are the dreaded enemies of death. He leads a relatively harmless life—the result of centuries of adaptations; then, out of the blue, an epidemic occurs; his host sickens, and the world he has ever known becomes pestilential and deadly; and, if as a result of circumstances not under his control, his stricken body is transferred to another whom he, in turn, infects, he does so without guile, from the uncontrollable need for nourishment, with death already in his own entrails. If only for his fellowship with us in suffering, he should command a degree of sympathetic consideration.”

**Seasonal and Geographic Distribution.** Typhus is more or less continuous, propagated among primitive people living in the colder climates, who because of their poverty, lack of facilities for maintaining personal cleanliness, and the character of their clothing are accustomed to infestation of lice. These conditions are realized in many parts of the world—in Russia, Poland, Siberia, southeastern Europe, Asia Minor, China, North Africa, Mexico and the Andean regions of South American countries. Transmission occurs during all months of the year, but incidence increases in the colder months as a result of the crowding together and lack of bathing, etc.

From these primitive native populations, among whom the disease is more or less constantly prevalent, it is propagated from time to time to adjacent human communities where conditions for spread are temporarily favorable. Such conditions are realized particularly among military and refugee populations during the disturbed conditions of wars.

Historically, typhus has been associated with war, disaster and famine. This was tragically illustrated by experiences in Europe during World War II, particularly in Germany. How devastating the disease can be under such disturbances has been described by Gordon (1948). Similarly, epidemics raged over Japan and Korea in 1945 to 1946 (Scoville, 1948). During this period, over 30,000 cases of epidemic typhus fever were reported. No prefecture of Japan nor province of Korea escaped. The case fatality rate was 6 to 10 per cent.

During the nineteenth century, typhus was frequently imported into the United States with the arrival of shiploads of infested immigrants. Localized epidemics were precipitated but after the middle of the century conditions were evidently not favorable to its continuous propagation in this country. During the Civil War, in 1861 to 1865, it was an unimportant cause of morbidity. The last epidemic in the eastern United States was caused by the importation of immigrants in New York City in 1893. Since then, except for an occasional case imported from Europe or Mexico and a small outbreak among the Navajo Indians in 1915, the United States has been free from louse-borne typhus. There are not enough lousy people in this country to support passage of the disease agent.

**Vaccine.** Many methods have been tried for producing suspensions of rickettsiae in adequate quantities to be used for vaccination. In 1933, Weigl attempted active immunization by using the phenolized intestinal contents of lice infected per rectum with *R. prowazeki* obtained from the brains of guinea pigs. The technic of infection is difficult. Two or three hundred lice are necessary to provide sufficient vaccine for one person; large scale immunization by this method is not practical. Castaneda (1938) and Durand and Giroud in 1940 used suspensions made from infected rodent lungs inactivated by the addition of formalin. Blanc and Baltazard, in 1941, &

ed a method of obtaining a suspension of attenuated murine typhus rickettsiae from flea feces. Since this vaccine contained living rickettsiae, immunity was developed at the price of development in the patient of an active, usually inapparent, infection. In 1940, Cox and Bell prepared an epidemic typhus vaccine based upon use of tissue culture. This vaccine consisted of a killed suspension of *R. prowazekii* grown on the yolk sac membrane of the chick and purified by centrifugation. Concentration of the effective antigenic material led to a vaccine which is satisfactory not only from the point of view of potency but also with respect to commercial production. Epidemic typhus vaccine used by the U. S. Army during World War II consisted of 10 per cent yolk sac suspension with the Breinl strain of *R. prowazekii* extracted by ether. The vaccine contains both rickettsial bodies and the antigen. Two doses of 1 ml. each are given, preferably separated by an interval of one month. The protection afforded is thought to last for six months or more. Stimulating or booster doses should be given at least annually or before entering an area of exposure.

A critical evaluation of protection afforded by this vaccine under conditions of actual exposure is not yet available. The evidence gathered from various observations leads to the conclusion that the risk of attack is reduced, the course of the disease is modified, and that the probability of a fatal issue is decreased (Gilliam, 1947; Sadusk, 1947). In addition to this, there is the important observation that man can be infected with difficulty, if at all, when permitted to feed upon a patient with typhus who has been previously vaccinated.

**Control of Epidemics.** In the presence of a typhus epidemic, the first step is to make provision for early diagnosis of cases and case finding. All reported cases should be immediately investigated. If the patient is found to have fever, headache, the characteristic rash, the house should be temporarily quarantined. The patient and familial contacts, their clothes and bedding, should be disinfested with dusting. While the members of the family are restricted to home for 14 days, infected cases of typhus fever should be removed to an isolation hospital. On being admitted to the receiving ward at the hospital all clothing should be removed immediately from the patient, dusted with DDT powder, and stored in a suitable container. The hair of the head, axillary and pubic regions should be collected and destroyed. The patient is then bathed, given clean bedclothes and sent to an isolation ward. Proper provision should be made for medical care of patients with antibiotic resistance. If possible, typhus immunes should be employed as attendants in the hospital. In any event, they should be properly instructed as to the danger of infection. Bed lice, should receive typhus vaccine at frequent intervals, and be kept under continual supervision.

**Local and Zonal Delousing.** Louse disinfestation squads or dusting teams should be organized for mobile operations. The first point of attack is the household of the patient and his immediate associates. Disinfestation should be extended as rapidly as possible to the neighboring family groups and concentrated upon the neighborhoods or zones in which cases are reported. Dusting of these persons, their clothes and bedding, should be done in their homes. As opportunity develops, the disinfestation should be extended to include as much of the population as practical to reduce the total amount of lousiness in the community.



Vaccination teams should be organized consisting of a doctor, nurse and clerk. Their responsibility is to vaccinate all persons in a focal area except the patient. Under epidemic conditions, it will probably be necessary to give two doses of vaccine, one week apart. These preliminary inoculations should be followed by a "booster" dose one month later if it seems practical. Such measures are apparently effective in bringing epidemics to an end (Wheeler, 1946; Gordon, 1948; Scoville, 1948).

**Control During Inter-Epidemic Periods.** Epidemic typhus decreased and disappeared from many parts of the world as civilization advanced and lousiness of the population decreased. It is a socio-economic problem as it is so closely woven with primitive living conditions, squalor, ignorance, and poverty.

That it is possible to temporarily reduce louse infestation of a community has been demonstrated by Montoya and Osejo (1948) using DDT and phenylcellosolve in control of pediculosis in Colombia. Application of these insecticides to 98 per cent or more of the population reduced louse infestation rate of 65 to 70 per cent to 5 per cent or less. These authors advanced the hypothesis that this level, if maintained, was sufficiently low to preclude typhus outbreaks and reduce the incidence of the disease to a position of minor public health importance. However, in order to maintain this low level, it would be necessary to repeat the delousing operation on the whole population at intervals every three or four months, unless their conditions of living were improved.

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## RECRUDESCENT TYPHUS

*(Brill's Disease)*

In 1910, Dr. Nathan Brill called attention to a typhus-like disease occurring in New York City. It was similar to typhus in its clinical course but relatively mild in the case fatality rate was less than 1 per cent. He noted that it seemed to appear especially among Jewish immigrants from southeastern Europe. It showed no tendency toward familial spread. The disease was sporadic and occurred more frequently in the summer months than in the winter. He was inclined to believe that he was dealing with a new clinical entity and called it "An infectious disease of unknown etiology." In 1912, Anderson and Goldberger were successful in the inoculation of a rhesus monkey with the blood from a case of Brill's disease in New York. They found that infection rendered monkeys immune to subsequent inoculation with the same passage virus. Furthermore, monkeys that were previously infected with murine typhus were found to be immune to Brill's disease and vice versa. From these observations, they concluded that Brill's disease was in fact identical with louse-borne typhus fever. Following these publications, there were reports of cases of Brill's disease from scattered cities in the United States. Even though these cases could not be traced directly to contact with a recently imported case of typhus, it was assumed that they originated either from infected lice or clothing contaminated with louse feces brought into this country by immigrants from European areas in which epidemic typhus existed.

Later studies of endemic typhus in southeastern United States (Maxcy, 1926a), suggested that it was similar to Brill's disease clinically and epidemiologically; in other words, that Brill's disease was actually murine typhus. However, Zinsser (1934) isolated from cases of Brill's disease in Boston, by animal inoculation, three strains of typhus, all of which corresponded in every respect to the louse-borne type, but the male guinea pigs did not exhibit the Neil-Mooser reaction. He then reviewed the epidemiological distribution of those cases of Brill's disease in New York and Boston up to 1934. He was able to obtain records of 538 such cases and found that 100 per cent occurred in individuals of foreign birth, 90 per cent were of a single ethnic group, Jews, 94 per cent of whom were born in those regions of southeastern Europe in which typhus had been endemic and often epidemic. Of 126 cases about which data were available, 76 per cent had been in this country over 10 years, the remainder from 1 to 10 years; in only two could the origin of infection be attributed to immediate contact with foreign sources. No connection whatever could be traced between cases and there was no domiciliary or occupational association. To explain this selection, Zinsser advanced the hypothesis that the cases observed in New York and Boston represented recrudescences of infections originally acquired many years previously when the individual had been living in a European country where typhus had been epidemic. He suggested that recrudescence cases might serve to maintain continuity of prevalence by bridging breaks in the chain of man-lice propagation, and that this was the manner in which the European virus had survived in continental foci for centuries.

In 1943, Plotz reported that the sera of 23 patients with Brill's disease gave higher titers in the complement-fixation test with classical epidemic antigen than with the murine antigen. Furthermore, the epidemic antigen completely absorbed



the agglutinins from the sera of Brill's disease while the endemic antigen only partially removed these agglutinins. It has also become apparent that Weil-Felix reaction may be negative or only doubtfully positive in many cases of Brill's disease (Schoenbach, 1949). Recently, Murray and others (1950) carefully studied patients with Brill's disease located in hospitals serving communities with large numbers of foreign-born Jews. Seven of these came under observation on the fifth to eighth day of illness. All were foreign-born Jewish immigrants. Six of the seven patients gave a history of having had a typhus-like illness while living in Europe. Probably little significance can be attached to the usual patients' recollection of previous typhus. Price (1955) has reported the recovery of *Rickettsia prowazekii* from lymph nodes of two patients who had migrated to the United States from Russia more than 20 years previously and who had had no known exposure to infection since that time. Serological tests showed them to have complement fixing and virus neutralizing antibodies to *R. prowazekii* before and after a surgical operation. In each of these seven cases, diagnosis of Brill's disease was established by clinical observation and laboratory data. In each instance, body lice fed upon the patient during the first week of illness were found to be infected with typhus rickettsiae. These seven strains were carefully studied on experimental animals by cross immunity tests and by serologic tests (Murray and Snyder, 1951). The results indicated that all seven had the characteristics of *R. prowazekii*. These observations added confirmation to Zinsser's hypothesis that patients with recrudescent attacks of latent infection residing in louse-infested communities provided a mechanism of interepidemic survival.

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#### MURINE TYPHUS

(*Endemic Typhus, Flea-Borne Typhus*)

Following the identification of Brill's disease with Mexican typhus by Anderson and Goldberger in 1912, there appeared from time to time reports of sporadic cases of what appeared to be mild typhus in scattered localities of the eastern and southeastern United States, in the Federated Malay States and in Australia. Maxcy (1926a, b) reviewed these reports and presented the results of the clinical, etiological and epidemiological observations on 197 cases collected in Alabama and the City of Savannah, Georgia, between 1922 and 1925. On the basis of the assembled evidence, he concluded that a disease clinically indistinguishable from typhus fever

cept with regard to its relative mildness and low fatality rate, was endemic in the theastern United States. The epidemiological characteristics were at variance with the concept of man-to-man transfer by lice. An hypothesis that seemed to afford a more probable explanation of the mode of transmission was that a reservoir of infection existed other than in man, and that this reservoir was in rodents, probably rats or mice, with accidental transmission to man through the bite of some parasitic bloodsucking arthropod—fleas, mites, or possibly ticks. This hypothesis was subsequently explored by many investigators in this country and abroad, leading to a relatively complete understanding of the disease now known as murine typhus.

**Clinical Course.** The onset is fairly rapid with chills, fever, headache, and nausea. The eruption usually appears about the fifth day; it may appear as early as the second or as late as the ninth day. The evolution of the eruption is rapid, becoming general in the course of 24 hours. The soles of the feet and the palms of the hands are usually spared. At first erythematous in character, as the eruption increases the color changes from a dull red to a darker hue with a purplish tinge and some petechial spots. It reaches maximum intensity in four to six days and begins to subside. In the majority of instances the skin becomes clear by the time convalescence is established. In the milder cases the eruption may be extremely evanescent, limited to a few spots scattered over the body which are visible for only a few hours when the temperature is elevated. The occurrence of cases without eruption seems highly probable but their frequency is unknown. The patient may have a slight hacking cough. In the early stages, nausea, vomiting, refusal of food are common manifestations. In about one fifth of the cases the sensorium remains clear throughout the illness. In the remaining four fifths the degree of involvement varies from slight dullness and apathy, or a combination of dullness with nervousness and irritability. In about one third of the cases there is delirium at some time during the course of the illness; it varies from night terrors to a complete disorientation and confusion. In the very severe cases, which are occasionally encountered, particularly in old people, the patient may go into coma and die during the latter part of the second week. One of the most striking features of the disease is its uniform duration. An analysis (Maxcy, 1926b) of 94 cases showed that 36 per cent terminated between the third and fifteenth days and 86 per cent between the twelfth and sixteenth days. Four of the 94 cases reached normal about the tenth day (abortive cases) and four complicated cases remained ill for 21 days or more. Although the illness lasts but a few weeks, a patient is usually prostrated and in a weakened condition at its termination. Not infrequently it is another week before he can get out of bed and a month or two before he can resume work. He is likely to be nervous and depressed for some time.

**Laboratory Diagnosis.** The differential and total count of white blood cells are generally within normal range. The serum shows a rising titer of agglutinins for *Brucella* OX19 (Weil-Felix reaction) beginning about the end of the first week and reaching maximum during convalescence. A rise in titer to a dilution of 1:160 or higher is regarded as significant. In similar manner, a rise in titer for a complement-fixing antibody for rickettsial antigens occurs. It is possible to standardize the antigen so that it will distinguish between antibodies specific for epidemic (louse) typhus and for murine typhus. Specific agglutination of rickettsial antigens is less frequently



used. Recovery of the causative agent by inoculation of experimental animals is not a practical procedure for the ordinary diagnostic laboratory.

**Inoculation of Experimental Animals.** Reference has previously been made to the inoculation of experimental animals with epidemic typhus. The causative agent usually can be recovered by inoculation of a guinea pig with an emulsion of blood clot obtained from the patient in the first week of his illness. The guinea pig shows a febrile reaction of the same character as that observed with epidemic typhus but differing in that on passage in male guinea pigs the scrotal reaction (Neil-Mooser) is constantly observed during the height of the fever. Guinea pigs recovering from an infection with murine typhus are solidly immune to epidemic typhus and vice versa. In smear preparations made from the exudate stained with Giemsa, or the method described by Macchiavello, the causative agent, *R. mooseri*, can be demonstrated in large mononuclear cells. In its morphology it is indistinguishable from *R. prowazeki*.

**Arthropod Transmission.** The work of Dyer and his associates in 1931, established that the tropical rat flea, *Xenopsylla cheopis*, is the principal vector of murine typhus from rat to rat and from rat to man. *R. mooseri* were recovered from fleas taken from wild rats caught on premises where cases of murine typhus had occurred. Experimentally, it was found that *Xenopsylla cheopis* becomes infected with *R. mooseri* when allowed to feed on typhus-infected rats; that infected fleas readily transmit typhus from rat to rat; that the rickettsiae are present in the feces of infected fleas; that the rickettsial infection may be transmitted by rubbing the feces of infected fleas into the abraded skin of guinea pigs and that infected fleas may retain the infection for at least 52 days. These observations have been supplemented and confirmed by many investigators. Rickettsiae are found multiplying in the gut cells and malpighian tubules but not in the salivary glands of the flea. Up to the present no one has demonstrated transovarial passage from one generation to another in fleas.

Other fleas found upon rats can be infected experimentally, viz., *Leptopsylla segnis*, the mouse flea; *Nosopsyllus fasciatus*, rat flea; *Echidnophaga gallinacea*, chicken flea; and *Ctenocephalides felis*, the cat flea. This is also true of a rat mite *Liponyssus bacoti*, and of a rat louse, *Polyplax spinulosa*. There have been reports of recovery of typhus virus from specimens captured in nature of the chicken flea, the cat flea, and the rat mite, *L. bacoti* (Kohls, 1948). Thus, while several arthropods could act as vectors from rat to rat, their importance in maintaining the infection in rat populations in nature is unknown. The geographic and seasonal distribution of murine typhus corresponds to what is known about the seasonal and geographic distribution of the tropical rat flea, *X. cheopis*. This flea is also known to change hosts and to attack man, and is apparently the principal vector concerned in transmission of the disease.

**Rodent Reservoir.** During the same year that Dyer and his associates recovered a murine strain of typhus rickettsiae from an emulsion of rat fleas, Mooser and others (1931) isolated a similar strain from the brain of a rat trapped in Belknap prison in Mexico City. Experimentally inoculated, the Norway rat has an inapparent infection manifested by the development of a positive Weil-Felix test and a positive complement-fixation reaction and by immunity to subsequent inoculation with homologous material. In 1938, Pailip and Parker recovered the agent from brain

white rats 370 days after original infection. How long such animals remain active for their ectoparasites has not yet been determined.

The value of the complement-fixation test as an indicator of past infection in commensal rats was established by Brigham and Bengtson (1945) who found from 0 to 81 per cent sera positive in rats captured in certain southern cities. This method has been found extremely useful in establishing focal infection in rat populations and following the course of the enzootic in relation to control measures. In San Antonio, Texas (Davis, 1948), 34.7 per cent of adult roof rats (*Rattus rattus*), 51.4 per cent of adult brown rats (*Rattus norvegicus*) positive for typhus complement-fixing antibodies.

In addition to domestic rats, house mice (*Mus musculus* and *Mus wagneri*) and the field mouse (*Peromyscus polionotus*) have been found infected in nature. A wide variety of rodents and other small domestic and wild animals have been found susceptible to experimental infection (Brigham and Dyer, 1938; Philip, 1948). In a limited survey of animals, exclusive of commensal rats, in southwest Georgia, 3,202 sera from 37 species were examined by the complement-fixation test for murine typhus (Morlan and others, 1950). Sera from 12 species of animals, including the opossum, cotton tail rabbit, fox squirrel, house mouse, rice rat, cotton rat, old field mouse, cotton rat, dog, Florida skunk, weasel, and blue jay, were found to be positive in low titers. Rickard (1951) presented evidence that the finding of positive complement-fixation tests up to a dilution of 1:64 with the sera from caught cotton rats, was not of specific significance and did not indicate previous experience with murine typhus. Accordingly, it cannot be assumed that positive complement-fixation tests in low titers in various species of birds and animals necessarily indicate such an infection. Up to the present, therefore, there is no convincing evidence of the existence of a reservoir of *R. mooseri* in animals other than the commensal rat, although the infection may occasionally be passed to associated wild rodents.

**Prevalence.** The biological mechanism involved in the maintenance of murine typhus in a natural environment is now clear, at least in outline. The principal and probably only reservoir of infection of consequence is in commensal rats. In this species, the infection is propagated from the infected animal to the susceptible by the mediation of ectoparasites, but particularly by *Xenopsylla cheopis*, the tropical rat flea. Occasionally, man is accidentally infected by a rat flea which has strayed from its natural host. The frequency of occurrence and distribution of the disease among human populations is thus conditioned by several factors, the principal ones of which are the following: (1) the relative numbers of commensal rats in the community; (2) the number of ectoparasites per rat, with particular reference to *Xenopsylla cheopis*; (3) the frequency with which the infection is being transmitted from infected to noninfected rats; (4) the extent and intimacy of exposure of human beings in a community to tropical rat fleas. The possibility of transmission from rat to man by the rickettsiae in flea feces through the air-borne respiratory route is a remote possibility, but the relative importance of this mechanism is unknown.

Commensal rats are concentrated upon premises where food, water and harborage are available. In towns and cities generally, these conditions are realized, especially in the older business sections. The risk of infection is, therefore, generally greater among persons employed in handling food, employees of groceries, butcher

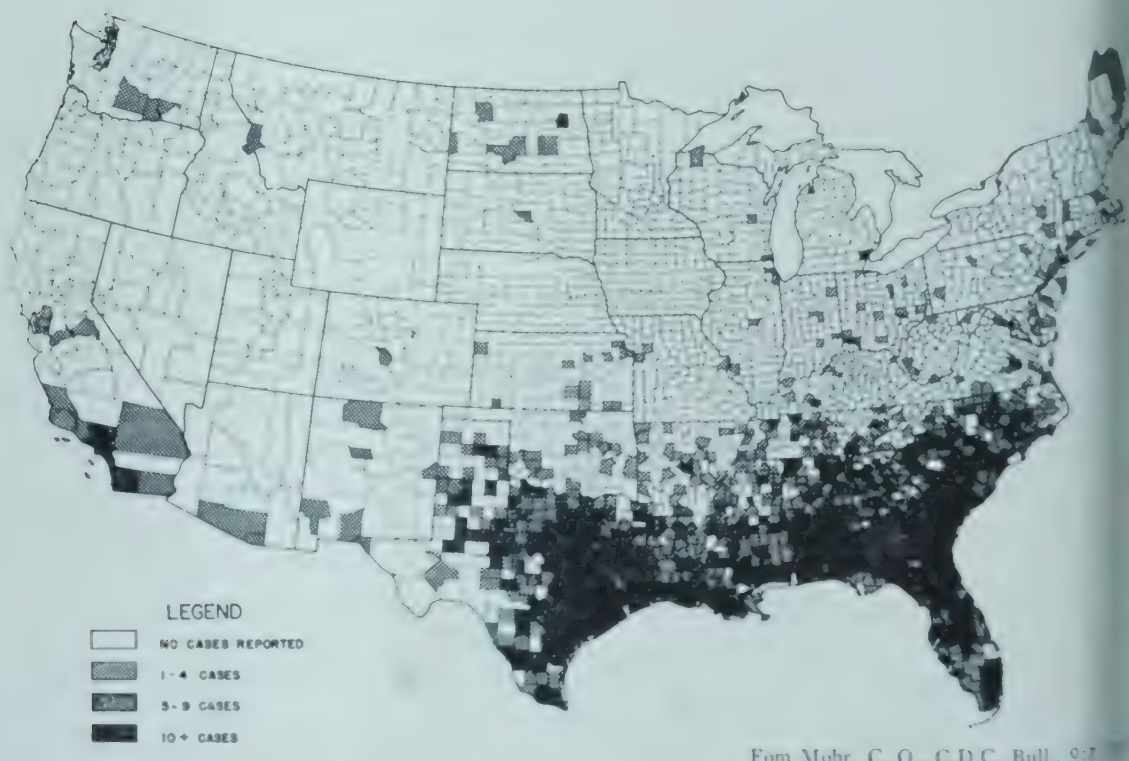


shops, seed stores, markets, etc. For this reason, cases of murine typhus are apt to be more frequent among males than females and relatively more frequent among adults than children. Local variations determine the exact pattern.

Seasonally, the incidence of murine typhus in human populations is greatest during the summer months, decreases in the fall, and reaches a low point during the middle of the winter. This is apparently determined by the numbers and activity of fleas, particularly of *Xenopsylla cheopis*, in relation to temperature and humidity and their access to man.

The disease is by no means limited to urban communities, since in many rural areas crops such as peanuts and corn afford abundant supply of food for commensal rats and consequently many rural homes are heavily infested.

During the two decades following the discovery of murine typhus in the southeastern United States, the number of cases recognized and reported by physicians increased annually, and the geographic area involved was extended. The peak was reached in 1944, when the total number of cases reported was 5,213, most of them occurring in nine southeastern states and in southern California (see Fig. 6-3). Since that time there has been an abrupt decrease. To what extent this is due to



From Mohr, C. O., C.D.C. Bull., 9:7

Fig. 6-3. Reported cases of endemic typhus fever in the United States, 1941 through 1954.

natural trend downward of the rat and flea population or to active control measures is unknown. Very recently, the decline has been accelerated by more exact diagnosis with laboratory confirmation. There were only 163 cases in 1954.

Since the original observations, natural infection of commensal rats with murine typhus has been demonstrated by recovery of strains or by serological procedures.

Jamaica, Brazil, Colombia, Peru, the Mediterranean basin, Russia, Poland, Germany, Rumania, Manchuria, North China, Malaya, the Philippines, Indochina, India, South Africa, Java and Australia.

**Control.** Since the disease is not contagious from man to man, there is no need for isolation of patients nor for restrictions upon the movements of household associates. In the hospital, cases can be treated on the open wards without special precautions. Chloramphenicol (chloromycetin) (Smadel, 1949) and aureomycin (Hoenbach, 1949) are reported to be effective in shortening and alleviating the severity of the disease.

The occurrence of a human case is a signal of the existence of an enzootic among feral and feral rats. The first step in control is to ascertain, if possible, the location of the place of exposure, whether at work, at home or at some place temporarily visited. A careful history is taken of the movements of each patient during the time period from 6 to 14 days preceding the onset of his symptoms, and this information is utilized, foci of infection may be located by common experience. Suspected premises should be immediately dusted with DDT for suppression of rat fleas; subsequently, rat control measures are undertaken. Persons exposed to infection on the premises may be given murine typhus vaccine to reduce the risk of the disease. While these measures are indicated in emergency situations, the prevention of murine typhus, as of bubonic plague, will depend upon measures conducted over a long period of time to reduce the rodent and flea populations in a community. It has been demonstrated (Hill and Morlan, 1948) that in an area where the probability of rural residents acquiring typhus fever was equal to or greater than that for residents of some urban communities it is possible to control this disease by the county-wide application of 10 per cent DDT in pyrophyllite to rat runs and harborage. In the absence of other rodent ectoparasite or typhus control measures, the murine typhus fever incidence was significantly reduced in two counties in Georgia, as was shown by comparison with previous experience in these counties and by concurrent comparison with data from an adjacent county.

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## ROCKY MOUNTAIN SPOTTED FEVER

Rocky Mountain spotted fever was known along the Snake River in Idaho as early as 1873, but the first clinical description of the disease in a medical journal was given by Maxey (1899). He noted that the disease occurred invariably during the spring months and was contracted by persons while residing or sojourning in or near the mountains, and that it was much more common in men, occurring most frequently among prospectors, miners, sheep herders, and cattlemen. Wilson and Chowning, in 1902, suggested that the wood tick was the transmitting agent, and that an animal reservoir existed. Ricketts, in 1906, began studies which demonstrated the presence of infected ticks in nature and the hereditary passage of the virus from one generation of ticks to the next. McCalla, in 1908, published the results of an experiment performed in Boise, Idaho. He removed a tick from a spotted fever patient and produced the disease in two volunteers by permitting the tick to feed on them. Ricketts, in 1909, reported successful transmission of spotted fever by the wood tick, *Dermacentor andersoni*, and described the micro-organism which he had observed in smears prepared from the blood of man, monkey, guinea pig, and from the tissues of the tick. The following year, Ricketts and Wilder showed by cross immunity experiments that Rocky Mountain spotted fever and typhus were separate and distinct entities. Wolbach (1919) reported the results of his careful etiologic and pathologic studies and named the causative organism *Dermacentor xenus rickettsi*. He called attention to the intranuclear multiplication of rickettsiae in tick tissue.

Up to 1930, it was thought that Rocky Mountain spotted fever was confined to 11 states of the northwest, although one case had been reported in Indiana. In connection with field investigations of typhus in the southeastern United States it was noted that cases living in the rural districts in the northern tier of states and urban dwellers vacationing in the country suffered from a very severe disease which did not exactly correspond to the clinical picture of endemic typhus. A high proportion of these cases gave history of tick bites within a short time preceding onset. Davis and others (1931) noted that many cases observed during the spring and summer of 1930 differed clinically from the disease as described by Brill, Maxey, and others and closely resembled Rocky Mountain spotted fever. Two strains of virus, established in guinea pigs from the blood of cases occurring in a rural section of northern Virginia, were subjected to intensive study with the result that they were found to be immunologically indistinguishable from a strain of spotted fever isolated from ticks in the Beaver Root Valley of Montana. Since that time, Rocky Mountain spotted fever has been shown to be widely distributed in the United States and present in two provinces of western Canada, and in two states of Brazil (exanthematic type of Sao Paulo) and in Colombia, South America (Tobia fever).

In the eastern and southern United States, the common dog tick, *Dermacentor bilis*, was found to be the vector. There is some evidence to indicate that dogs contract the infection in an inapparent form. In the southwest United States, have also been traced to the lone star tick *Amblyomma americanum*; in Brazil common vector is *Amblyomma cajennense*. Many other tick species have been found to be experimentally infectible but epidemiologically unimportant in transmission of the human disease (Kohls, 1948).

**Clinical and Pathological Features.** The clinical course of the human disease is similar to that described for typhus fever. In severe cases of spotted fever the rash tends to be more hemorrhagic and to be accentuated on the extremities, particularly at the wrists and ankles. Occasionally, a lesion may be detected at the site of the bite, but a typical primary eschar is lacking. Nervous and mental symptoms are common; restlessness, insomnia, disorientation, and delirium are manifestations of involvement of the central nervous system. Prostration may be extremely marked in the beginning, merging into coma, with death as early as the sixth to eighth day. Convalescence is apt to be slow, and may be complicated by visual hallucinations, deafness, and mental confusion. Although recovery may be delayed, it is usually complete in the end. The case fatality rates vary directly with age, as in typhus, and there is also considerable variation in the virulence of strains in different parts of the country. The crude fatality rate for reported cases in the United States is about 18 per cent. Recent reports indicate that the early institution of treatment with antibiotics—chloramphenicol (chloromycetin) and aureomycin—greatly lessens the course of the disease and decreases the risk of death (Ross and others, 1948; Pincoffs and others, 1948).

**Laboratory Diagnosis.** Confirmation of the diagnosis is afforded by the Weil-Felix reaction which becomes positive with *Proteus* OX19, usually with OX2, and sometimes with *Proteus* OXK during the second week of the illness. The complement-fixation test becomes positive about the same time. The causative agent may be isolated and identified by inoculation of guinea pigs with blood obtained from a patient early in the course of the illness. The incubation period of spotted fever in guinea pigs is four to five days but, as in typhus, it may be prolonged in the laboratory generation. The fever tends to be considerably higher than in typhus, ranging from 106° to 107° F. A fatal termination is common, although varying with different strains from 100 per cent to 0. With the more virulent strains there is scrotal necrosis. In others, this necrosis is inconspicuous and the scrotal reaction resembles that seen in guinea pigs inoculated with murine typhus. *D. rickettsii* may be grown in tissue culture and in the chorio-allantois and yolk sac of developing chick embryos. The rickettsiae are killed in a few minutes by exposure to moist heat at 50°C, to chemical agents, and in a few hours by desiccation at room temperature.

**Natural Propagation and Distribution.** Selection of the disease in the western United States for persons exposed to the open range and the seasonal limitation to spring and early summer months was explained when the tick vector species was identified as *D. andersoni*. This is a wood tick, which in the adult form is found widely distributed upon the large mammals, particularly cattle and sheep, in the western range country from the eastern portion of the Pacific Coast states to northern North and South Dakota, and from New Mexico on the south to Alberta, Saskatchewan, British Columbia, on the north. Adult ticks live two to four years or



more. Engorged females deposit their eggs in the soil. The winter is passed in the adult, nymphal or egg stage. Larvae or seed ticks emerge in the late spring and take a blood meal from small animals. If successful, they moult to the nymphal stage which may not become active until the following spring. Many small animals, especially rodents, are susceptible to infection with the virus of Rocky Mountain spotted fever, and after having been bitten by an infected tick develop an inapparent form of the disease. During the period of time that the causative agent is in the peripheral circulation, these animals serve as a source of infection for the uninfected larval, nymphal or adult ticks which chance to feed upon them concurrently. The rickettsiae pass through the stage to stage development of the tick and are carried to successive generations in decreasing numbers by transovarial passage. Infection is thus maintained in nature by the alternation of the small animal and tick host. Dogs and field mice (*Microtus pennsylvanicus*) appear to be important vertebrates in the transmission chain of *R. rickettsii* in Maryland (Price, 1954). A relatively large percentage of this species of field mice has been found to have specific complement fixing and toxin neutralizing antibodies to *R. rickettsii*.

The distribution of the disease in eastern and southern United States was explained when it was discovered that the vector is *Dermacentor variabilis*. The hosts of this species of tick are mainly domesticated animals, such as a dog, horse or cow. Therefore, exposure is common about areas of habitation. Accordingly, the disease occurs more frequently among children and females than is the case with the western spotted fever (Topping, 1941).

**Prevention.** Prevention depends primarily upon exercise of personal care and protection against tick bites. Persons who are exposed to known infected areas should frequently examine the clothing and body for ticks. Usually, the tick does not become attached to its host immediately but travels about for several hours. It has been shown that the chance of receiving infection from the bite of a tick is directly proportional to the length of time the tick has fed. Ticks should be removed from the person or from a pet with small forceps or with a piece of paper. The skin area involved should be swabbed with tincture of iodine and the forceps disinfected with heat or chemicals. Hands should be washed with soap and water after such operation.

A vaccine is prepared from rickettsiae grown in the yolk sac tissue of fertilized hen's eggs and inactivated by the addition of phenol 0.4 per cent and formalin 1 per cent (Cox, 1939). Evidence from animal experiments and from use in human beings indicate that the yolk sac preparation affords significant protection. It should be administered in the spring or early summer before the beginning of the tick season and should be repeated each year, since the maximum degree of protection conferred is less than a year. The degree of immunity afforded is relative, but the chance of subsequent infection is lessened and the risk of death is greatly reduced. The adult dose consists of two injections, 10 days apart, of 2 ml. each, child should receive half of this amount.

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### BOUTONNEUSE FEVER

Connor and Bruch (1910) described a mild typhus-like fever which they believed to be an endemic disease of Tunis, North Africa, and proposed the name boutonneuse fever. It was subsequently observed to occur in the vicinity of Marseille, France. The disease was thought to resemble the mild typhus reported by and Maxcy in the United States. However, it was noted that somewhere on the body of each case could be found a small black eschar, "tache noir." The cases presented gave no history of louse infestation. At first it was thought to differ from Weil's disease by the fact that the Weil-Felix reaction was generally negative. More recently, however, it has been demonstrated that an increase in the agglutinins for *Brucella* OX19 can usually be found. Experimental evidence that the disease was transmitted by the common dog tick, *Rhipicephalus sanguineus*, was presented by and Conseil (1931). Cross immunity tests in guinea pigs (Badger, 1933) indicated that Boutonneuse fever and Rocky Mountain spotted fever were immunologically related if not identical. However, subsequent investigators pointed out that an ulcer was produced at the site of experimental bites by ticks infected with *Dermacentor rickettsii*, whereas an ulcer and the accompanying lymphadenopathy was constantly produced at the site of a bite of a tick infected with the agent of Boutonneuse fever. The latter was, therefore, designated *Dermacentor rickettsii*.

Boutonneuse fever is now known to have a wide geographical distribution. It has been reported from most of the Mediterranean countries and from the Crimea. Available evidence suggests that the disease described as Kenya typhus and South African tick-bite fever are probably identical with Boutonneuse fever, although caused by different species of ticks. A recent review has indicated the widespread distribution of this human tick-borne rickettsiosis in Africa.

### INDIAN TICK TYPHUS

In a series of publications between 1917 and 1927, Megaw and his associates drew attention to a typhus-like disease in India which differed from classical louse-borne typhus in its clinical and epidemiological characteristics. They occurred sporadically and in small groups of cases in widely scattered rural localities in the hills and scrub areas of Kumaon hills and Central India plateau. The season of occurrence appeared to be the winter in the less elevated regions and summer in the



higher regions. Patients had nearly always been exposed to bites of ticks, and in some cases the tick was actually found fastened to the body. The incubation period was from one to three weeks. Duration of fever was from 12 to 16 days in most instances but sometimes lasted as long as three weeks. The case fatality was low. The Weil-Felix reaction with *Proteus* OX19 was negative. The disease differed from Boutonneuse fever and from scrub typhus in the absence of any local ulcerated sore (eschar) and local lymph adenitis. For these reasons, and because it seemed to resemble Rocky Mountain spotted fever somewhat, it was called Indian tick-typhus by Megaw, although at no time was experimental evidence produced which definitely incriminated the tick as a vector. Recently, Topping and others (1943) reported the results of complement-fixation tests on three sera obtained from patients in Mysore State which indicated the causative agent was more closely related to spotted fever than to the typhus group.

### SIBERIAN TICK TYPHUS

Reports from Russian workers indicate the occurrence of a typhus-like, tick-borne fever in central and eastern Siberia. Sera of patients give a positive Weil-Felix reaction to *Proteus* OX19. The principal vector is *Dermacentor nuttalli*. The rickettsial agent has been demonstrated from ticks collected in nature and natural infection has been found in certain small rodents. The relationship of rickettsial strains recovered from these sources to *Dermacentroxenus rickettsii* and *conori* has not been established.

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### SCRUB TYPHUS

#### (*Tsutsugamushi* Disease, *Mite-Borne Typhus*)

Typhus-like fever ascribed to the bite of a minute insect was known to natives of certain river valleys in Honshu, Japan, almost a century ago. K. Tana (1899) presented a careful description of its clinical and epidemiological features and identified the vector as a mite found in large numbers in the infected valleys during the summer months when most of the cases occur. From 1906 to 1922 tsutsugamushi disease was the subject of intensive investigation by Japanese scientists. In the meantime, typhus-like fevers had been described under many names endemic in localities scattered throughout southeast Asia and the adjacent archipelago. As the result of many studies (Blake and others, 1945), it has become clear that these belonged principally to two categories: (1) murine, or flea-borne typhus

ch the sera from patients agglutinate *Proteus* OX19, and (2) mite-borne or scrub typhus, indistinguishable from tsutsugamushi disease, in which the sera from patients give a positive Weil-Felix reaction with *Proteus* OXK. The latter disease has been recognized as occurring in Formosa, the Pescadores Islands, the Philippines, India, Federated Malay States, Burma, India, Ceylon, Sumatra, Java, New Guinea and adjacent islands, and Northern Queensland, Australia. During World War II, scrub typhus was far more important as a cause of morbidity and mortality in military forces operating in the southwest Pacific area and in the China-Burma-India theater than was louse-borne typhus to the forces operating in the Mediterranean and European Theaters.

**Clinical Course.** The distinguishing characteristics of this form of typhus is the absence of the primary lesion, or eschar, usually single, sometimes multiple, at the site of the infective mite bite or bites. Although not always present, an eschar can usually be found by careful examination somewhere on the patient. The eruption is more erythematous, macular and evanescent than in louse-borne typhus. While the course of the fever may be terminated in two weeks, it is not unusual for it to last three or four weeks. More or less extensive pneumonitis is common and lesions of the myocardium may give rise to impairment of cardiac function, sometimes circulatory failure. Case fatality rates vary in different geographic areas from about 2 per cent to 20 per cent. Prognosis becomes increasingly grave with advancing age.

**Laboratory Diagnosis.** Laboratory confirmation of the diagnosis is afforded by the Weil-Felix reaction becoming positive during the second week of the disease. The reaction is positive to *Proteus* OXK and commonly negative to *Proteus* OX19 and OX2. About the same time, complement fixation becomes positive with an antigen made from a suspension of *Rickettsia tsutsugamushi*. The etiologic agent can be easily recovered and demonstrated by intraperitoneal inoculation of mice with a minute amount of defibrinated blood obtained from a patient early in the course of the disease.

**Natural Propagation.** *Rickettsia tsutsugamushi* is primarily a parasite of trombiculid mites, of which two closely related species have been identified as vectors, *Neotrombicula kamushi* and *T. deliensis*. During the larval stage these mites attach and feed on various species of wild rodents and occasionally upon other animals, such as cats, marsupials and upon birds. Rodents have been found to be infected in nature with *R. tsutsugamushi*—*Microtus montebelli* in Japan, *Rattus concolor browni* in New Guinea, *Rattus concolor concolor* in Burma. Infection contracted by the larvae while feeding is passed by stage-to-stage transfer through the nymph, free-living adult and egg to the next generation. Since larvae feed only once upon a host, transmission from rat to rat to man requires transovarial passage of the *R. tsutsugamushi* in successive cycles of development of the trombiculid mite.

**Distribution and Prevalence.** It follows that the distribution of the human disease is determined by the ecology of the affected locality, i.e., with regard to the number of rodents, numbers and kinds of ectoparasite species of mites and the opportunities for the larval mites to make effective contact with human beings. The mites live in the upper layer of the soil in the organic detritus which covers it, and crawl for short distances up on the grass and other vegetation. Accordingly, the disease shows an occupational selection for the agricultural laborers working or digging in new or overgrown fields and abandoned plantations, explorers, prospectors, soldiers, etc. Its seasonal distribution is determined by climatic factors. In



Japan, it is limited to the four summer months, from June to September, while in tropical areas, such as New Guinea, transmission may occur throughout the year.

**Prevention.** In the treatment of cases, precautions with regard to isolation are not necessary. The handling of patients is much the same as that for other typhus-like fevers. The investigations conducted by Smadel and his associates (1950) have demonstrated very clearly that the course of the disease can be modified and controlled by the administration of the proper doses of chloramphenicol (chloromycetin) at proper intervals, and for a suitable length of time. Efforts to produce an effective vaccine have not been successful up to the present time (Berge and others, 1949) because of the diversity in antigenic composition of various strains of *R. tsutsugamushi*. Prevention of exposure depends upon protection from mite bites in an endemic area. A camp site should be cleared and the brush and grass burned before occupation. The individual may be protected by wearing clothing that has been treated with miticide chemicals. During World War II, methods were developed for impregnating uniforms in terminal laundry rinse and with a soap solution containing dimethyl phthalate and benzyl benzoate (Bushland, 1946).

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#### OTHER RICKETTSIAL DISEASES

In recent years, two human diseases, and possibly a third, have been found to be due to rickettsiae; namely, Q fever, rickettsialpox, and trench fever. In each of these the clinical pattern is distinctive and cannot be classified as typhus-like.

#### Q FEVER

Derrick in 1937 investigated the occurrence of a series of cases of an unknown fever among slaughter house and dairy employees in Queensland, Australia. He described the clinical course in nine cases, and by inoculation with blood from each of the nine patients he was successful in establishing the infection in guinea pigs. No organism could be seen in or cultivated from human or guinea pig material, and it appeared likely that the infecting agent was a virus. Infected guinea pig liver was thereupon sent to Dr. F. M. Burnet of Melbourne, Australia, who in transferring the infection into mice was successful in discovering rickettsial bodies in their spleen. Subsequent work (Burnet and Freeman, 1937) established the rickettsial etiology of this disease and the organism was named *Rickettsia burneti* by Derrick in 1941.

In another part of the world, about the same time, Davis and Cox (1937)

covered a filter-passing agent from a group of 200 *Dermacentor andersoni* ticks collected near Nine-Mile Creek about 32 miles west of Missoula, Montana, U. S. A. They described the reaction of guinea pigs to the infectious agent and found white mice and white rats to be susceptible. It was shown to survive in, and to be transmitted by, nymphal and adult *D. andersoni* that ingested the virus in the larval stage, and survived through the eggs deposited by infected females to be transmitted to the progeny. It was found to be a minute, Gram-negative pleomorphic rickettsia-like organism that occurred both intra- and extracellularly in the infected tissues of guinea pigs.

By a fortuitous circumstance, a member of the staff was accidentally infected and the human pathogenicity of the agent demonstrated. Moreover, the resemblance of this human infection to the new disease described by Derrick in Australia was recognized. "One way" cross immunity tests suggested that the infectious agent isolated in Montana and the causative agent in Q fever were closely related, or identical. A comparative study of the rickettsial strains from infected ticks in Montana and from Q fever was conducted by Burnet and Freeman (1939). It was concluded that the Montana strain belonged to the same species as *Rickettsia australis*.

During the spring of 1940, 15 cases of "pneumonitis" occurred among the 153 employees of one building of the National Institutes of Health (Hornibrook and Brown, 1940) in Washington, D. C. These 15 patients all showed roentgenographic evidence of pneumonic infiltration. In addition to these, there were a few others who had a similar but somewhat milder attack who either gave negative x-ray findings or in which roentgenograms were not obtained. Four attempts were made to isolate the causative agent from proved cases of pneumonitis. The identical agent was isolated in three of the four and later identified as the rickettsia of Q fever. No valid evidence was produced that personal contact or the intervention of an arthropod vector was responsible for the transmission of the disease. Two important inferences were drawn from this experience. The type of infiltration revealed by the x-ray, and certain other clinical characteristics of these cases, were similar to the syndrome termed "primary atypical pneumonia." From this time on, therefore, Q fever was included with the other pulmonary infections and a differential diagnosis of primary atypical pneumonia. The epidemiological study of the circumstances under which the outbreak occurred, led to the conclusion that these accidental laboratory infections were air-borne. It was notable, however, that there were no secondary infections among familial associates of the cases.

On the basis of these early observations, there followed a series of contributions which have shown that Q fever is an important human disease in localized areas of the world.

**Clinical Recognition.** Neither the history nor clinical course are sufficiently characteristic to establish a diagnosis. The incubation period ranges from 14 to 26 days, with a mean of 19 to 20 days. The onset is generally abrupt, with fever, chills, rigors, general weakness, malaise, headache, and muscular aches. Symptoms referable to the upper respiratory or gastro-intestinal tracts are inconspicuous. About the fifth or sixth day a mild dry cough develops in the majority of patients, and many complain of pain in the chest. Careful physical examination at this time may reveal the presence of a few rales and slight diminution of resonance. Evidence of pul-



monary involvement, indistinguishable from that of primary atypical pneumonia, is found by roentgenogram in practically all patients, even including those who are so mildly ill that they would not ordinarily seek medical care. The febrile period may last from 1 to 14 days, but in about half the patients the fever is of three to six days' duration. Convalescence is rapid. The disease is rarely fatal.

**Laboratory Diagnosis.** Confirmation of the diagnosis of Q fever by serologic means is accomplished either by the agglutination or complement-fixation technique. It is highly desirable that early and late specimens of sera be tested for antibodies in order to demonstrate the appearance of antibodies during convalescence or an increase in titer. Complement-fixing antibodies are detectable between the seventh and thirteenth day in practically all cases and rise steadily to a maximum titer, usually in the range of 1:160, which is reached about the twenty-first day (Robbins and others, 1946).

Isolation of *R. burneti* from the blood of patients during the febrile phase may be accomplished by guinea pig inoculation. The usual incubation period in the guinea pig, following intraperitoneal inoculation of 2 ml. of blood virus, is from four to six days, the extremes are 2 to 10 days. The temperature is continuous in most of these animals for from two to eight days, averaging between 40° and 50° C. The common febrile period is from two to four days. Certain strains regularly cause death in guinea pigs, even on inoculation of only a few infectious doses; others are lethal only when highly concentrated material is used for inoculation. All strains are readily adapted to growth in the yolk sac of chick embryos.

**The Etiologic Agent.** Because of its filtrability, Philip in 1943 expressed the individuality of the causative agent of Q fever by placing it in a separate subgenus *Coxiella*. It differs from the causative agents of typhus, spotted fever and tsutsugamushi disease in resistance to physical and chemical agents. *Coxiella burneti* is relatively resistant to desiccation. This quality, together with the fact that the feces of infected ticks are rich in viable organisms, is important in the transmission of the disease. Of similar significance is its resistance to heat. Although thermal death points as understood in bacteriological sense were not obtained, Q fever organisms were found by Ransom and Huebner (1951) to survive temperatures as high as 63° C when suspended in milk, sealed in vials and submerged at 30 to 40 minutes in water baths. Final concentrations of 0.5 per cent formalin failed to inactivate per cent yolk sac suspensions of *C. burneti* after 96 hours at 4° C but 1 per cent formalin was effective in 72 hours.

**Treatment.** Treatment with tetracycline antibiotics or chloramphenicol appears to be effective in suppressing symptoms. These drugs should be administered orally and continued for several days after the patient is afebrile. If relapse occurs treatment should be reinstated.

**Propagation and Transmission.** According to Derrick (1953) at least 10 species of ticks have been found naturally infected. They came from widely separated localities from four continents. Nine species have been found able to transmit *C. burneti* from host to host under experimental conditions. Multiplication takes place in the epithelial cells lining the gut, and the lumen contains numerous rickettsiae. Transovarial passage has been demonstrated in three species. Ticks and tick feces are the most concentrated natural sources of *C. burneti*. Apart from ticks, no other arthropod except the human louse has been found naturally infected.

Ticks provide a high titer geographically widespread reservoir of *C. burneti*. Their hosts assist them either by taking part in the tick-animal-tick cycle of transmission or, where transovarial passage occurs in the tick, simply as accessories necessary for nourishment.

The search for naturally infected animals and birds has resulted in the isolation of *C. burneti* from six species: cows, sheep, goats, bandicoot, merion and pigeon. The first three provide a notable source of infection for their environment, periodically and intensively contaminating the soil with placenta and postpartum discharges; more continuously at a low titer through milk.

Because of the high resistance of *C. burneti* to heat and desiccation, it can survive for comparatively long periods of time in soil, dust, contaminated hides, wool, etc. The conditions under which most of the human infections occur are consistent with the concept that in a majority of cases *C. burneti* are air-borne and the mode of entry is through the respiratory tract.

In the United States, natural infections have been demonstrated in *D. andersoni* in western Montana and Wyoming, and *D. occidentalis* in Oregon and California, *Ixodes americanus* in Texas, *Haemaphysalis leporis-palustris* in Virginia, and *Ixodes dentatus* in Virginia and New York (Kohls, 1948). Considering that the agent has been recovered from five species of ticks from widely scattered sections of the United States, and that three of these species commonly attack man, it is remarkable that as yet no human infections have been definitely traced to ticks or other arthropods.

During World War II, Q fever was found to occur endemically and epidemically in the Mediterranean countries of Italy, Corsica and Greece (Commission on Acute Respiratory Diseases, 1946). The evidence identified Q fever with "Balkan grippé" and the occurrence of outbreaks in Athens, Greece, in the winters of 1943-44 and 1944-45. During the winter of 1944-45 and the spring of 1945, seven outbreaks of the disease, initially diagnosed as atypical pneumonia, which occurred in American troops stationed in Corsica and the North Appennine region of Italy were investigated. The mode of transmission of the agent was not ascertained; the epidemiological evidence pointed toward an extrahuman source and possibly an intermediary vector.

When Q fever was discovered in the metropolitan area of Los Angeles in 1947, extensive epidemiological studies were undertaken by the National Institutes of Health with cooperation of the California State Department of Health and Agriculture and the Los Angeles City and County Health Departments. The results are being published in a series of reports. According to Bell and others (1950), Q fever has been occurring endemically in the Los Angeles area and it is highly probable that more than 50,000 persons have been infected with *C. burneti* in recent years. It appears that a considerable portion of these infections were manifested as an identified acute illness with fever for two or more days.

Early in the course of these studies, it was noted that proximity to dairies, by reason of occupation or residence, was a common factor in the histories of more than 50 per cent of the cases (Huebner and others, 1948). Except for dairy workers, it was noted that the infected persons rarely used milk from nearby dairies. It was found in fairly extensive serological surveys that 10 to 20 per cent of dairy workers in the Los Angeles area possessed serum antibodies for Q fever. Epidemiologic



studies showed that, of 60,000 cattle shipped into the area annually, between 40 and 50 per cent acquire asymptomatic infection within six months after being brought on the infected premises. These animals shed *C. burneti* continuously or intermittently in the milk for periods of time exceeding one lactation period. The organisms were isolated on autopsy from the mammary gland and adjacent lymph nodes of an infected cow. Dairy cows were shown to be sources of gross contamination of the environment by the post-parturient passage of highly infected placental membranes (Luoto and others, 1951). *Coxiella burneti*, the causative organism of Q fever, was recovered from raw milk from four widely separated dairies in Los Angeles County. Further studies showed the commercial pasteurization substantially reduced but did not entirely eliminate the infection from milk (Huebner and others, 1949). The organism survived 41 days in refrigerated butter made without pasteurization (Jellison and others, 1948). An epidemiological analysis showed that the human cases were rarely ever direct sources of infection for other persons, and that insects and arthropods played little if any role in the spread of the disease to human beings. The most frequent and by far the most important sources of human infection were local dairy cows, their very young calves, and some of their raw products, particularly raw milk and hides. Persons most likely to be infected were those who used raw milk in the household, those whose residence had been located near a dairy or livestock yard, those who had worked in industries handling live or recently killed dairy cows and young calves, e.g., employees in dairies and meat packing plants and fat rendering plants, employees handling the raw products of such animals, e.g., employees of creameries and hide plants. Human cases were found in association with infected herds of goats and sheep. In these animals the rickettsia leave the host not only in the milk and placenta but have been found in the feces and in wool tags and fleece of naturally infected sheep (Winn and others, 1953; Abinanti and others, 1955).

Further investigations by Lennette and others elicited the fact that Q fever was by no means limited to the Los Angeles area in California but was occurring in other localities of the state.

**Prevention.** The prevention of natural exposure to Q fever constitutes an unsolved problem. Fortunately, the risk is limited. While the primary cycle may involve small vertebrates and their tick ectoparasites, this source of infection appears to be of no consequence to man. Aside from the ingestion of contaminated raw foods, the principal medium of dissemination seems to be air-borne contaminated dusts. One obvious preventive measure is the proper pasteurization of milk of cows, goats and sheep. A vaccine has been produced that seems to be valuable for the protection of laboratory workers but is still in the stage of experimental development. Isolation of cases is unnecessary, since communicability from man to man has not been demonstrated.

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# RICKETTSIALPOX

In 1946, an unusual febrile illness with varicelliform rash became epidemic in a New York City housing development. One hundred twenty-four cases were identified with the assistance of attending physicians and investigated by representatives of the New York City Health Department and the National Institutes of Health. The clinical features of this new disease have been fully described by Greenberg and others (1947a).

The onset of the disease is usually heralded by a primary papular skin lesion which undergoes vesiculation followed by the formation of a black eschar, which heals with scarring. The lesion may attain a diameter of 5 to 15 mm. and is usually distinctly larger than the lesions of the subsequent generalized eruption. Regional lymph nodes are usually enlarged and sometimes tender. Constitutional symptoms usually begin two to seven days after the appearance of the initial lesion. They include chills or chilly sensations, fever (the temperature ranging up to 104° F), headache, muscular pains and lassitude. The characteristic feature of the disease is the rash, which appears at any time from the first to the sixth day of the fever. It begins as erythematous maculopapules from 2 to 10 mm. in diameter. In from 48 to 72 hours, a variable proportion of these develop at the apex of the papule a small vesicle containing cloudy fluid. The vesicles usually give way to small crusts which heal without scarring. Lesions appear on the face, trunk, extremities, rarely on the palms and soles, and occasionally on the tongue, palate, buccal mucosa and pharynx. The eruption varies from very extensive to scanty, but lesions are found in more



than 90 per cent of cases. The fever, systemic symptoms and the eruption may last from 2 to 10 days. Leukopenia is more or less consistently present.

**Laboratory Diagnosis.** Etiological studies were begun by Huebner and his associates (Huebner, 1948) on July 25, 1946. During the following three months, nine identical strains of rickettsiae, subsequently named *Rickettsia akari*, were isolated: two from patients; six from rodent mites, *Allodermanyssus sanguineus*; and one from a wild house mouse, *Mus musculus*. In mice, a definite, sometimes lethal, illness was produced by this agent. *Rickettsia akari* inoculated intraperitoneally into guinea pigs produced a nonfatal disease similar to Fièvre Boutonneuse and endemic typhus. The incubation period of four or five days is usually followed by an irregular low grade fever of from one to four days' duration. A consistent sign of the disease in the male guinea pig is an inflammatory scrotal reaction. Growth on the yolk sac of fertile hen's eggs is prolific. Immunologically, *R. akari* is related to *Dermacentor troxenus conori*. The Weil-Felix reaction is negative with Proteus OX19, OX2 and OXK. The diagnosis of rickettsialpox may be confirmed by the development in convalescence of a high titer of complement-fixing antibodies in tests with antigens of *R. akari* (Greenberg, 1948).

**Transmission.** There is considerable evidence that rickettsialpox is transmitted to man through the agency of the rodent mite, *Allodermanyssus sanguineus* Hirst. The occurrence of an initial skin lesion in this disease, as in tsutsugamushi disease, is presumably the result of inoculation of the infectious material by a mite bite. The disease has a very limited focalized distribution. While multiple cases occur in a particular domicile, there is no evidence of spread by direct contact from person to person. Wherever a careful search has been made, house mice infested with *Allodermanyssus sanguineus* have been found in close proximity to the cases. Finally, strains of rickettsiae recovered from human sources, from pools of mites, and from the house mouse have been found to be identical by cross immunity and serological tests.

**Prevalence.** The epidemiology of the disease has been described by Greenberg and others (1947b). Investigations conducted in New York City revealed the fact that cases were occurring in five of the boroughs. Pike and others (1950) reported a serologically proved case occurring in a resident of Boston. It may be expected that the disease will be discovered in other communities, since *Allodermanyssus sanguineus* is known to occur in Indianapolis, Indiana; Tucson, Arizona; and the District of Columbia; and possibly in many other communities. Exposure to infection is associated with dwelling conditions which are favorable to harborage for mice. *Allodermanyssus sanguineus* is not uncommonly found attached to and feeding on the mice, the usual site of attachment being the rump. However, these mites wander some distance from mouse nests to adjoining walls and floors. Obviously, the prevention is a matter of suppression of mouse infestation on domestic and occupational premises.

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### TRENCH FEVER

(*Five Day Fever, Wolhynian Fever*)

During the early period of World War I, a hitherto unknown mild disease characterized by febrile relapses became widely prevalent in some of the armies in northern Europe. McNee and others (1916) described the clinical syndrome under the name of trench fever. Typically, the onset was sudden, accompanied by headache, dizziness, pain in the legs, especially the shins, injection of the conjunctivae and a sharp rise in temperature. Usually the fever subsequently assumed an relapsing character. In a majority of cases, an eruption of small erythematous macules or papules appeared, scattered principally over the chest, back and abdomen. The eruption appeared as early as the second day of fever or was observed prior to or during a relapse. It often disappeared within 24 hours. There were many variations in the clinical course. From three to five relapses were common and in some cases had six or seven. Sometimes relapse occurred after several months of quiescence. Complete recovery was the rule; the disease was almost never fatal. Because of an obvious association with military personnel in the front lines, it was called "trench fever." The term Wolhynian fever was applied to it because the supposed source of the infection was in that area. It was called "five day fever" because of the interval between relapses. Whichever name was used, it became evident that it was one of the most important causes of manpower loss in the fighting armies. During 1917-18, before the influenza epidemic, it was the cause of from one fifth to one third of all cases of illness in the British armies in France. Two commissions were set up—the British Trench Fever Commission and the American Red Cross Commission—to investigate the cause, pathogenesis, mode of transmission and prevention. Their findings have been summarized by Swift (1920).

According to this early work, the many clinical forms of the disease are apparently not due to different types of the causative agent, but to single or multiple infections of a single type. The intensity and duration of an attack seemed to depend on the balance between dose and the virulence of the infecting micro-organism and development of immunity by the human host. Attempts to recover the agent from the blood of patients by the inoculation of artificial media tissue culture or chick embryos were unsuccessful. Small laboratory animals were not susceptible. Recently, it has been demonstrated that a reaction and characteristic febrile relapsing course could be produced in the baboon and in the *Macacus rhesus* monkey (Looser and Weyer, 1953a, b).

In the early work it was necessary to resort to the inoculation of human volunteers.

Under suitable conditions, the agent could be passed through a Berkefeld filter, but the results were irregular. The agent was found occasionally in the sputum of patients, often in the urine, and always in the blood at some stage. Experimentally it was transferred from man to man by intravenous or intramuscular injections. The incubation period varied from 5 to 20 days. After an interval of from 5 to 10 days



following the infecting feed it was found in the excrement and bodies of lice (*P. humanus*) that had fed several times on trench fever patients. When a louse had started to excrete the agent, it continued to do so for the remainder of its life. It was not passed from one generation of lice to the next through eggs.

The life span of the infected arthropod host is not materially shortened. There was remarkable correspondence in the infectivity of louse excrement and the time of appearance of rickettsia-like micro-organisms. They were observed on the surface of epithelial cells lining the gut, and free in the lumen, apparently multiplying extracellularly. Evidence supports the concept that they are the causative agents of trench fever. They have been classified as *Rickettsia quintana* by Schmincke in 1917 (syn. *R. wolhynica*, *R. pediculae*) (Mooser and others, 1948).

Man appears to be the reservoir host for *R. quintana*. Where it multiplies in the body, whether in the blood or in the organ tissues, is not known. After infection of the human host it circulates in the blood stream for a variable time—from a few days to months—with or without clinical symptoms. After months, even after years of latency, relapse or recrudescence may occur. Its alternate host is the human louse, which may harbor *R. quintana* for a few weeks at most. Its survival requires an ecology which is favorable to man-to-man transmission by lice.

A critical study to determine the effective use of antibiotics in treatment has not been made. As with epidemic typhus, control or eradication of the disease follows upon measures designed to reduce lousiness. In World War II, trench fever was of little or no importance as a cause of morbidity in the military forces. Knowledge of its prevalence among civil populations is fragmentary.

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# 7

## CONTROL OF ARTHROPOD VECTORS AND INFESTATIONS

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Medical entomology deals with the arthropods which cause or carry human diseases. The concept of disease transmission through arthropods developed especially during the latter part of the nineteenth century, through the thinking of men like Nott, Beauperthuy, Finlay, and King, who, from various epidemiological observations, reasoned that malaria and yellow fever could be caused by mosquito attack. Meanwhile sounder evidence was accumulating through the experiments of Henshaw, Fedtschenko, and Melnikoff on the transmission of the filaroid worms, *Brugia malayi* and *Dracunculus*, through Cyclops and of the dog tapeworm through dog fleas and fleas. The greatest impetus to this line of thinking was furnished by Manson's demonstration in 1878 that the filaria worm, *Wuchereria bancrofti*, underwent a definite developmental cycle within the body of a mosquito, *Culex fatigans*. In 1894-95, Bruce showed that the tsetse fly was responsible for Nagana in Africa; in 1889, Smith and Kilbourne proved the role of the tick as a vector of Texas fever of cattle; this was followed by the discoveries of the role of mosquitoes in the transmission of malaria by Ross in 1897-98 and yellow fever by Reed in 1900. Since then the importance of the role played by arthropods in the epidemiology of human and animal diseases has been made abundantly clear, and it is recognized that knowledge of the taxonomy and biology of the vectors is essential to a proper understanding of the epidemiology and control of the arthropod-borne diseases. The Phylum Arthropoda is divided into several classes, two of which contain bloodsucking species that are of importance as disease vectors. The class *Insecta* (Hexapoda) comprises the insects, which are recognized by their external, shell-like skeleton, segmented body, and jointed legs and antennae. The insect body is divided into a head, a leg- and wing-bearing thorax, and an abdomen. Usually, there are two pairs of wings; but among the medically important forms, the flies have the second pair of wings reduced to small balancers or halteres, while the lice, fleas, and bedbugs, through parasitism, have lost all vestige of wings. The bloodsucking insects are found in four systematic divisions called Orders. These are the *Diptera*, or flies; the *Siphonaptera*, or fleas; the *Anoplura*, or lice; and the *Hemiptera*, or bugs. The class *Arachnida* includes the ticks, mites, and spiders, as well as other forms such as crabs and lobsters of no medical importance. The *Arachnida* differ from insects especially in that the body is divided into two regions, the cephalothorax and abdomen; there are eight pairs of legs in the adult, and wings and antennae are lacking.



Two other classes of arthropods which must be noted are the *Scorpionida*, or scorpions, possessing a poisonous sting at the tip of the tail-like terminal portion of the abdomen, and the class *Chilopoda*, the centipedes, which have the front pair of legs modified to form poisonous claws.

The insects, in their development from egg to adult, undergo a remarkable series of transformations, a process which is called "metamorphosis." There are several types of metamorphosis, depending upon the phylogenetic position of the insect. The primitive wingless silverfish and bristletails are ametabolous, that is, they undergo no marked changes. The ametabolous development of the highly specialized lice is due in part to the loss of the wings through parasitism. The insects which undergo a gradual metamorphosis have young which resemble the adult insect except that the wings are small and develop gradually in external pads. The young of these insects are called nymphs. In incomplete metamorphosis the legs and wings develop externally, but the immature stages, called naiads, are adapted for an aquatic existence, while the adults are aerial. Comstock says the naiads are "sidewise developed." May flies and dragon flies are examples of this type of metamorphosis. In complete metamorphosis the developmental stages are the egg, the larva, the pupa, and the adult. In the worm-like larva, the legs and wings develop internally. The pupa is a so-called resting stage; within the pupa the larval tissues are broken down and transformed into those of the adult.

#### THE ROLE OF ARTHROPODS IN MEDICINE

The role of arthropods in medicine is that of being directly responsible for pathological conditions in man and animals, or they may act as carriers of disease agents. Under the former are included hypersensitivity to insect bites or stings; allergic responses to scales and hairs from wings and bodies of butterflies, moths, and other insects; and direct invasion of the body by mites and parasitic fly larvae.

In transmitting pathogenic organisms, arthropods may be simple mechanical vectors, or they may be biological hosts for pathogens whose existence depends upon completing part of the life cycle within the body of the arthropod. Typhoid bacilli, yaws spirochetes, and other organisms which are present in the discharges and exudates of the diseased body may be carried mechanically by flies or other insects directly to a new victim or to food and drink about to be ingested. Arthropods are biological hosts for viruses, bacteria, spirochetes, protozoa, and helminths. Within the body of the vector the viruses, bacteria, and possibly the spirochetes undergo a simple multiplication; this is called the *propagative* type of development. The protozoa and helminths undergo part of their life cycle within the arthropod, they are transmitted biologically, and when there is no multiplication of the parasite the transmission is said to be *cyclodevelopmental*; when there is multiplication as well as a biological cycle, the parasite-vector relationship is called *cyclopropagative*. The host in which the sexual stages of the parasite occur is the *definitive* host; the asexual stages occur in the *intermediate* host. Thus man, and not the mosquito, is the intermediate host for the malaria parasites, while mosquitoes are intermediate hosts for the filarial worms. A certain length of time is necessary for the development of the parasite within the arthropod to the point where it can be transmitted biologically by the bite or dejecta of the vector; this is termed the *extrinsic incubation period*. Within mechanical transmission there is no incubation period. Hereditary trans-

ion refers to the ability of ticks and some of the mites to pass the disease organisms through the eggs to the succeeding generations; none of the insects can do this, although it has been claimed that the virus of pappataci fever can be passed ovarially through *Phlebotomus*.

### THE CONTROL OF ARTHROPODS OF MEDICAL IMPORTANCE

The epidemiology of the arthropod-borne diseases may be represented as being the links of a chain; the two end links, the patient (or animal reservoir host) and the uninfected person, are connected by the middle link, the arthropod vector. The vector is indispensable for the successful passage of the disease agent from the sick to the well. The whole purpose of control of the arthropod-borne diseases is to break the links of the chain, and one may separate the procedures for bringing this about into measures of a defensive nature or as measures of attack. Measures of defense include the use of protective clothing and repellents to discourage insect attack; the avoidance of those places in which there is danger of being bitten by infected insects, such as swamps and villages in which malaria mosquitoes become active at night, or tsetse-infested bush; and the use of bed nets and screens. These measures are usually applicable to individuals and relatively small groups of people who find themselves in an endemic area, but sometimes may be employed to great advantage in protecting communities or armies. Widespread use of repellents undoubtedly played a considerable role in prevention of malaria and scrub typhus among military personnel operating in the Pacific areas during World War II.

The older *repellents* such as oil of citronella or pennyroyal have fallen into disuse because of the far more effective compounds discovered during World War II. The repellents which have been used most widely are dimethyl phthalate, dimethyl pivalate, Indalone (n-butyl mesityl oxide oxalate), and Rutgers 612 (2-ethyl-1,3-bis(2-methyl-2-propenyl)-1,3-propanediol). A mixture of 6 parts dimethyl phthalate and 2 parts each of Indalone and Rutgers 612 is known as 6-2-2 and is effective against a greater number of arthropods than is any one of the ingredients. In general, these repellents will protect for two or more hours, even when the user is sweating heavily. They may be sprayed over the skin of the exposed parts of the body; they may be rubbed onto clothing by hand; or clothing may be impregnated through the use of solutions or emulsions. Care must be taken not to get them into the eyes; and as they are solvents for paints, varnishes, and plastics they will damage watch crystals and other objects made of plastics, synthetic clothes, and similar products. Repellency is a complicated phenomenon, and the mode of action is not yet well understood. A compound may repel one species but not another. More effective materials are being sought.

In Africa, large communities have been protected from sleeping sickness through the use of insecticides in areas where tsetse flies do not exist. Such measures do not reduce the vector density, but are effective in breaking the transmission chain through the prevention of contact of the vector with the source of infection or the potential host. The use of prophylactic drugs may also be thought of as being a defense measure.

The measures of attack are designed to destroy the middle link of the chain by greatly reducing or even exterminating the vector population. These may be divided into several categories, as given below.



**Naturalistic Control.** Animal populations are held in check through the forces of nature, such as the topography of the country, nature of the soil, climate, types of vegetation, availability of food, and the activities of predators and parasites. When these natural forces are unbalanced outbreaks of insects may occur. The replacement of indigenous flora with vast cultivated crops has favored certain species which have become agricultural pests; introduction of insects into new regions where their normal predators and parasites are absent may permit them to build up tremendous populations; and creation of artificial breeding places for mosquitoes through alteration of the topography by man may give an anopheline species the opportunity to multiply to the point where it becomes a health hazard. One might say, therefore, that natural measures are the most effective in keeping arthropods in control, and by naturalistic control we mean the conscious imitation of these natural forces by man. Its application requires an intimate knowledge of the life history and ecology of the arthropod. These measures may be very simple and economical, or they may be complex and involve huge and expensive engineering projects. But whether simple or complex, naturalistic control is the most effective measure because the environment is altered, more or less permanently, to make it completely unsuitable for the existence of the arthropod against which the work is directed. Not all naturalistic measures require engineering technics, but all engineering methods have as their objective the bringing about of natural control. Drainage, filling, the damming and flushing of streams, proper sewage disposal, sanitary garbage fills, and the like, whether planned directly for arthropod control or not, are all naturalistic measures which reduce or eliminate disease vector populations. Environmental sanitation may have a high initial cost, but has the advantage over other methods of control in that it is more effective and is not repetitive. The cost of maintaining the altered environment is usually small.

**Mechanical Control.** Under this heading we may include various mechanical devices which destroy insects. Hand catching of mosquitoes with a net or chloroform tube will destroy only a few individuals, but nevertheless, if practiced in an area where disease vectors enter houses, it may prevent transmission of diseases by regularly destroying infected individuals. Hand picking of ticks from the body, after exposure to them in their habitat, is an effective means of preventing the inoculation of rickettsial pathogens. Hand catching of tsetse flies by organized teams of fly boys has greatly reduced or even eradicated the flies and sleeping sickness from certain places in Africa.

Many types of traps have been designed to capture and destroy insects. Traps are valuable for determining the density of insect populations, and hence for showing the effectiveness of control campaigns. The New Jersey light trap is equipped with a fan which sucks insects, attracted by the light from a distance, into the trap where they are overcome by HCN fumes and fall into the killing jar at the bottom. These traps are especially effective in catching mosquitoes, and have been used widely in surveys and in control operations. Mosquito abatement organizations set an arbitrary low nightly mosquito count as their goal; when the count rises beyond this number it is realized that control procedures are not adequate. Stable traps which consist of screened sheds containing an animal such as a calf or horse as bait, will catch thousands of mosquitoes in one night if placed properly. The insects enter the trap through slits in the sides, or the door of the trap may simply be left

in during the night and closed early the following morning. The animal is retained by being placed in a properly constructed stall. Although traps may catch great numbers of mosquitoes and other insects, it must be remembered that the flies represent only a small proportion of the total adult population, and that as the reproductive potential of insects is extremely high, the uncaught adults will produce more eggs than are necessary for maintaining the population at normal density. Fly traps, sticky papers, and the like, may alleviate annoyance by reducing numbers of free-flying individuals in a restricted locality, but they do not reduce general fly density. Perhaps the most successful use of traps has been in tsetse control campaigns.

**Chemical Control.** The use of insecticides is often the only manner in which an arthropod can be attacked. Insecticides have the advantage of being immediately effective in destroying the disease vector, but they are expensive and must be used judiciously. During World War II, powerful new insecticides were discovered, and it was hoped that if used correctly over a sufficient length of time, some of them will eventually bring about extermination of certain disease vectors. There are three types of insecticides: stomach poisons, fumigants, and contact poisons.

*Stomach poisons* must be ingested in order to kill, and so can be used only against those insects which have chewing mouth parts. Such insects, armed with mandibles and maxillae, bite off parts of leaves or other food, and the poison may be spread over the natural food or it may be incorporated in an attracting bait. Stomach poisons are used widely in agriculture, as many of the insects attacking crops have chewing mouth parts. Insecticides used as stomach poisons are the cyanides, cryolites, phenothiazine, hellebore, phosphorus, thallium sulphate, and borax. Stomach poisons have little use in control of medically important arthropods, for most of these parasites have piercing-sucking mouth parts adapted for acquiring blood from their hosts. Up to the time DDT became available, Paris green was used widely as an anopheline larvicide. These larvae feed upon small particles lying in the surface film, and particles of Paris green are ingested with the food. The poison was distributed as a dust in an inert carrier at the rate of 1 pound of the Paris green to 1 acre of water. Phenothiazine has been shown to be highly toxic to mosquito larvae; hellebore and borax have been used to kill fly larvae in manure, and formaldehyde can be used as a poison in a sweet liquid to kill flies.

*Fumigants* are taken into the respiratory tract and so will kill regardless of the type of mouth parts possessed by the arthropods. They are valuable for control in grain storage bins, warehouses, greenhouses, and the like, where the insects cannot be reached by ordinary sprays or dusts, or where such insecticides might harm the material being infested. Since the development of the new residual insecticides, it is no longer necessary to resort to fumigants to solve most control problems involving insects of medical importance. They are still used extensively for extermination of rats in holds of ships; the object of this is rat rather than insect control (see Chapter 8). There is no question as to the effectiveness of fumigants; a house infested with bedbugs will be freed not only of these pests but of all other living creatures as well through adequate fumigation. But the elaborate preparations necessary, the expense, and the danger to occupants of the premises would make it preferable to select another method, especially since the newer insecticides will give results that are as good, or nearly so, as those obtained with fumigants.



*Hydrocyanic acid* (HCN) has been used very extensively as an insect fumigant. The gas may be generated by adding sodium cyanide to sulphuric or hydrochloric acid, or from liquid hydrocyanic acid stored in heavy steel cylinders, but usually the most convenient method is to use dry preparations. These are finely powdered calcium cyanide, or Fuller's earth or paper discs impregnated with liquid HCN. HCN fumigation should be carried out only by experienced operators.

*Sulphur* has been used as an insecticide in several forms. The gas  $\text{SO}_2$  may be produced by burning sulphur or by liberating liquefied sulphur dioxide. It is cheap, readily procurable, and it will kill household insects, but its disadvantages are that it tarnishes metals, rots fabrics, and bleaches pigments. Flowers of sulphur ointment and sulphur-impregnated soaps are effective for treatment of scabies, but may produce dermatitis; lime and sulphur dips have been widely used to destroy mites on domestic animals.

*Disulphide of carbon* ( $\text{CS}_2$ ) is an efficient insecticide, but a dangerous one, on account of its inflammable and explosive nature; every precaution must be taken to see that there is no fire, lighted cigar, etc., in or about the field of operation. The gas is heavy and has good powers of penetration; therefore, it is useful for destroying insects in grain storage bins, in clothing, furniture, and for insects which burrow into the ground or wood. It is used to kill bot larvae in the stomach of horses. It was extensively used in California in the plague campaign. A piece of waste the size of an orange was saturated with the liquid and the wet ball placed in the mouth of the squirrel hole. Wet clay was then stamped into the warren so that the gas would have no opportunity to escape. The gas kills not only the squirrels, but also the fleas on them.

*Carbon tetrachloride* ( $\text{CCl}_4$ ) may be used in place of carbon disulphide. It is neither inflammable nor explosive.

*Methyl bromide* ( $\text{CH}_3\text{Br}$ ) is used to combat various economic pests and also for fumigation of rodent burrows.

*Chloropicrin* ( $\text{CCl}_3\text{NO}_2$ ) may be used for household fumigation, and has the advantage of being extremely irritating and hence safer to use than other fumigants. The use of chloropicrin discoids as a warning prior to HCN fumigation of ships has saved several lives.

Other fumigants which have been used for household pests are ethylene dichloride ( $\text{CH}_2\text{Cl}.\text{CH}_2\text{Cl}$ ); ethylene oxide ( $\text{C}_2\text{H}_4\text{O}$ ), and naphthalene ( $\text{C}_{10}\text{H}_8$ ).

The most useful of the compounds used in public health insect control are the *contact insecticides*, which kill regardless of the type of mouth parts possessed by the arthropods. The important ones are listed below.

*Pyrethrum* is obtained from the dried flowers and buds of *Chrysanthemum cinerariaefolium*, *C. rosei*, and *C. marshalli*. Formerly it was used only as a powder and the lukewarm discussion of pyrethrum in earlier editions of this book were probably due to the relative ineffectiveness of the unstandardized powders and fumes produced by burning the powder with alcohol. The extraction of pyrethrum with kerosene and the chemical analysis of the insecticidal principle has made it possible to standardize the product sold commercially. The active material in pyrethrum was first thought to be two esters which were named "Pyrethrin I" and "Pyrethrin II." These, however, have proved to be mixtures, and Frear (1948) points out that more work is necessary to determine the nature of the substances

are designated as Pyrethrin I and II, and Cinerin I and II. These materials are stable, and decompose in the presence of light, air, and moisture. The freshly prepared extract should be purchased, and it should be stored in dark, tightly closed containers.

For routine use, pyrethrum may be purchased from the manufacturer as a 1 per cent concentrate; this represents the use of 20 pounds of flowers to make one gallon extract, and the extract is standardized to contain 2 gm. of pyrethrins in 100 ml. For ordinary use one part of the extract is diluted with 19 parts of kerosene (or other light petroleum oil) to make a 5 per cent solution; the final product, therefore, contains 0.1 gm. of the esters per 100 ml. of spray. This spray is highly effective against common household pests, but if applied too lightly, houseflies and other insects may recover after having been knocked down. The rapid paralyzing effect of pyrethrum is highly desirable in household space sprays. Another advantage is its harmlessness to man and domestic animals when used as an insecticidal spray. Disadvantages are the ability of insects to overcome the effects of too small doses, and its instability. These may be overcome in part by combining pyrethrum with one of the new slow but sure insecticides such as DDT, by the addition of synergists to increase the toxicity of pyrethrum, and by the use of antioxidants to delay decomposition.

Pyrethrum synergists include isobutylundecylenamide and sesamin. The latter was an ingredient in the earlier aerosol formulations, but it was found later that kerosene and mineral oils were just as effective. For control of arthropods of medical importance, the combination of piperonyl butoxide with pyrethrum seems to be especially promising. This material is marketed under the trade name of Pyrenone, and may be utilized as a solution, dust, dispersable powder, or aerosol. The piperonyl butoxide greatly increases the knock down and kill, and delays the deterioration of pyrethrins so that Pyrenone may also be of some value as a residual insecticide. The principal advantage of Pyrenone is that it may be used safely in food handling establishments and in other situations in which the use of the chlorinated hydrocarbons represents a distinct hazard.

Recently Schechter and others (1949) have synthesized esters of the cinerin I component of pyrethrum. This material, called allethrin, is only one of the four insecticidal esters in pyrethrum, but it appears to be about as effective against houseflies as is pyrethrum. The synthesis promises to have commercial possibilities at a cost lower than that of extraction of natural pyrethrins.

**Thiocyanates.** The thiocyanates possess insecticidal properties, and two which have been used as substitutes for pyrethrum are beta-butoxy-beta'-thiocyanodiethyl ether, and isobornyl thiocynoacetate. A trade name for the former is Lethane, and for the latter, Thanite. These may also be combined with DDT or another of the chlorinated insecticides; this will ensure rapid knock down and high kill.

**DDT.** The name DDT is a contraction of dichloro-diphenyl-trichloroethane. This material was first synthesized by Zeidler in 1874, but it was not until about the beginning of World War II that its insecticidal properties were discovered. The Sandoz Company of Switzerland showed that it was toxic to certain household and agricultural insects, and in 1942 the U. S. Department of Agriculture began its investigations which demonstrated its effectiveness in combating insects of medical importance. During the war DDT was used extensively for the control of mosquitoes,



flies, and lice in military establishments. The great advantages of DDT over other insecticides are its extreme toxicity to arthropods but apparent relative harmlessness to man and animals, and its stability, which permits it to kill arthropods for months after having been applied to a surface upon which the creatures will alight.

DDT is a white crystalline material. The technical grade contains from 70 to 77 per cent of the p,p' isomer, which is the most insecticidal of the isomers formed in the manufacture of the compound. The aerosol grade contains 97 per cent or more of the p,p' isomer; a pure grade may also be obtained. It is insoluble in water. Its solubility in solvents commonly used in insecticidal preparations is as follows:

SOLVENT	Gm. DDT/ 100 ML.
Kerosene, crude . . . . .	8-10
Kerosene, refined . . . . .	4
Fuel oil, No. 1 . . . . .	8-10
Fuel oil, No. 2 . . . . .	7-10
Xylene . . . . .	53
Acetone . . . . .	58
Cyclohexanone . . . . .	116

In public health work, DDT is used most commonly as a 5 per cent solution in kerosene or fuel oil. Cyclohexanone is used as an auxiliary solvent for DDT in the Freon aerosol formulations.

Emulsions are made by addition of a suitable emulsifying agent to a solution of DDT. A standard formula is as follows:

DDT . . . . .	25 gm.
Triton X-100 . . . . .	10 ml.
Xylene . . . . .	65 ml.
Water . . . . .	425 ml.

Dissolve the DDT in the xylene, add the emulsifier, and then add water to make 500 ml. of liquid containing 25 gm. of DDT. The final product is, therefore, a 5 per cent emulsion. Various modifications of this formula have been used. With suitable water, the amount of emulsifier may be reduced considerably.

Suspensions of DDT are made by mixing DDT-coated or impregnated diluents, plus a wetting agent, with water. "Wettable powders" of various strengths are available commercially. Advantages of the suspensions are that they have a longer residual effect, and are safer to use on plants and animals, as there is no oil solvent present for the DDT. The wettable powders are finding wide use as dips and sprays for domestic animals. A disadvantage of suspensions is that sediment tends to clog the sprayers.

Dusts containing 10 per cent DDT in pyrophyllite or talc have had their greatest public health use as louse powders.

DDT gains entrance to the body of the insect through the integument. Chitin, an important constituent of the arthropod cuticle, absorbs DDT readily; it has been suggested that penetration occurs through the sensory organs and intersegmental membranes. The mode of action is not yet clearly understood. A recent review of the subject is that of Metcalf (1948). Within a few minutes after contact with DDT the insect shows signs of nervousness; it then becomes hyperactive and soon its movements lack coordination and are accompanied by rapid tremors, so that the

walking become erratic; finally it is unable to move except for isolated and nishing twitching of the appendages. Death ensues gradually.

Common with most insecticides, DDT is poisonous to man, but there is a wide margin of safety if it is handled sensibly. Several fatal cases of DDT poisoning in have been reported, but it seems to be uncertain whether the DDT or the ents were at fault. The dangerous acute and chronic doses for man are not as yet n. DDT dust may be used safely on the skin and clothing, but DDT may be rbed through the skin in solvents. Ingestion of large quantities will produce symptoms. DDT has been shown to accumulate in the fatty tissues of animals, small amounts ingested with milk may accumulate to dangerous levels. When are sprayed with DDT, or their food is contaminated with it, small amounts are ted in the milk. The Food and Drug Administration has ruled, therefore, that is a contaminant, and so this insecticide cannot be used on dairy animals, in y barns, milk sheds, and the like, or on crops destined to be fed to dairy animals. DDD. DDD or TDE, 1,1-bis(*p*-chlorophenyl)-2,2-dichloroethane, or dichloro- enyl-dichloroethane is very similar to DDT. It is less toxic than DDT to fish, so is safer to use as a larvicide, but it is also less effective in general against ts of public health importance.

*Methoxychlor*. This compound, 2,2-bis(*p*-methoxyphenyl)-1,1,1-trichloro- ne, is another analog of DDT, which may be used against household and other ts, but it is not as effective as DDT. It is not as toxic as DDT to man and estic animals, and so has been approved for fly control in dairy barns and on y animals.

*Benzene Hexachloride*. Benzene hexachloride (gammexane, 666, BHC) is 1,2,3,4,5,6-hexachlorocyclohexane. In the manufacture of BHC several space ers are formed, of which the gamma isomer is the most insecticidal. The techni- grades available commercially contain from 12 to 90 per cent gamma isomer. urified grade may also be obtained, containing at least 99 per cent gamma er; this has been named Lindane. Benzene hexachloride is another insecticide was developed during World War II, but has not been used as extensively as . The technical grade has an objectionable musty odor, which limits its use in es. It may be used as a solution, emulsion, wettable powder, or dust. It is highly to arthropods and acts more rapidly than does DDT. It also affects the nervous m, causing increasing excitement, tremors, ataxia and convulsions. It is more ile than DDT and hence does not have as long a residual effect. It is rather toxic an and animals, and so should not be allowed to contaminate food. It is not mended for use on dairy animals. It is effective in sprays, dips, and washes for ontrol of ticks, but because the margin of safety between the concentration for ment and that which is toxic to animals is small, it must be used on animals care. The halogenated compounds must not be used on animals in combination arsenicals.

*Lindane*. The purified gamma isomer of benzene hexachloride can be used in n smaller concentrations, and is recommended for use in dairy barns at the rate 5 mg. per square foot. It should not be allowed to contaminate foods and it is ecommended for use on dairy animals.

*Chlordane*. Chlordane (Chlordan, Octa-Klor, 1068) is 1,2,3,4,5,6,7,8,8- chloro-3a,4,7,7a-tetrahydro-4,7-methanoindane. This is a dark, viscous liquid,



and may be used as a solution, emulsion, wettable powder, or dust. It is highly toxic to arthropods, but it does not have as long a residual effect as does DDT. It has found wide use in control of flies, and at present is the insecticide of choice for combating cockroaches. The U. S. Public Health Service recommends a 2.5 per cent emulsion as a residual spray in certain portions of houses, such as baseboards and around windows and doors. It must be used with caution as it is quite toxic to man and animals. Its margin of safety is too small to recommend its use on animals; it should not be used in dairy barns, nor should it be used where there is danger of contaminating foods.

*Dieldrin* ( $C_{12}H_6Cl_6O$ ) is one of the newer compounds that has been used extensively in the control of medically important insects. It is effective against adult mosquitoes if applied as a residual spray in houses at a rate of 25 mg. per square foot. It is highly toxic to other household pests, and it may also be used as a fly or mosquito larvicide. Because of its toxicity, it should not be used in dairy barns or on animals and must not be allowed to contaminate foods.

*Toxaphene* ( $C_{10}H_{10}Cl_8$ ) is toxic to arthropods, but in general it is less effective than DDT and so has not found wide usage in control of insects of public health importance.

Other compounds are being developed for use against public health pests, especially for the control of DDT-resistant flies and mosquito larvae. Some are extremely toxic to man and should be handled only by experienced operators. *Parathion*-impregnated cords, hung in suitable locations, have been effective against house flies. *Malathion* has been used in sugar or molasses baits for control of flies in barns. Under certain circumstances, the following insecticides may be employed against the public health pests: *EPN*, *Dilan*, *Dipterex*, *Diazinon*, *Heptachlor*, and *Aldrin*.

**Application of the Contact Insecticides.** The contact insecticides are used as larvicides in the breeding habitat of mosquitoes and other *Diptera*; they are incorporated in powders, ointments, and other preparations for treating the hair, skin, and clothing of man against externally parasitic arthropods; and they are used for the control of adult insects in the form of space sprays and residual sprays. Each method of application requires certain techniques, some of which will be described later; the purpose of the present section is to consider the use of space sprays and residual sprays for the control of adult mosquitoes, flies, and other household insects.

Space sprays consist of insecticidal solutions which are dispersed as finely atomized droplets by means of any of a number of spraying devices available on the market. The spray gun may be the hand-operated, pumping atomizer familiar to every householder or gardener, the knapsack sprayer, or the paint-sprayer type attached to a motor-driven source of pressure. The spray is directed at the flying insects or at the spot where they are resting. To bring about a kill, the insects must be hit with the spray.

Any of the contact insecticides listed above may be used in solution as a space spray. The chlorinated hydrocarbons will insure a high kill, but they act slowly, and it is often objectionable, for example, to have DDT-poisoned flies making erratic flights about and into food about to be consumed. To overcome this, pyrethrum or another knockdown agent may be combined with about a 1 per cent solution of DDT or similar insecticide. Federal specifications require a minimum of 0.13 gram of Pyrethrin I plus the accompanying Pyrethrin II in 100 ml. of insecticide. Knockdowns comparable to that obtained with this amount of pyrethrum

be obtained with a 2 to 5 per cent solution of thanite or lethane. The use of ergists will permit the use of smaller amounts of pyrethrum. The pyrenones cause a rapid knockdown and a high rate of kill.

A modification of the space spray is the *aerosol*. Insecticides may be dispersed being vaporized through heating in the presence of a smoke produced by burning combustible material. In 1941 Sullivan, Goodhue, and Fales showed that flies could be killed by vaporizing naphthalene on a hot plate immediately after corn cobs and sodium nitrate had been burned in an open plate. Thermal aerosols are employed for treatment of large out-of-doors areas, and are produced by specially constructed machines which utilize super heated steam or a hot air blast to break up emulsions, emulsions, or suspensions into particles of aerosol dimensions; or by air-sprayers equipped with an extension of the exhaust stack into which the insecticide is pumped and converted into a fine spray and aerosol by the heat and blast of the exhaust. For indoor use, Sullivan and his associates (1942) developed the liquefied aerosol, which consists of a solution of the insecticide in dichloro-difluoromethane or similar material which forms a gas at ordinary room temperature. The chilled, liquefied material containing the dissolved insecticide is placed in a small container or "bomb" equipped with a suitable nozzle. Opening of the nozzle releases the gas, carrying the insecticide with it, drifts into space and eventually contacts all exposed insects within the enclosed space. Very small amounts of the aerosol are needed. These self-propelled aerosols are most convenient for temporary control of household insects. During the World War II aerosol "bombs" were employed as an antimalarial measure to kill mosquitoes in barracks, tents, and other living and sleeping quarters of military personnel. They are used for treatment of airplanes before and immediately after landings to prevent the introduction of exotic disease vectors and pests.

Many formulations of aerosols have been tried. The earliest aerosols used by the armed forces during World War I contained 1 per cent pyrethrins and a small amount of sesame oil as an activator. Later DDT was used as the killing agent, but a small amount of pyrethrum was retained because of its knockdown properties. It has also been shown that either vegetable or mineral oils could be substituted effectively for the sesame oil. Sample formulae are as follows:

FORMULA G-382

Pyrethrum (20% pyrethrins)	5 per cent
DDT	3 " "
Cyclohexanone (auxiliary solvent)	5 " "
Lubricating oil S.A.F. 30	2 " "
Freon 12	85 " "

FORMULA G-651

Pyrethrum (20% pyrethrins)	6 per cent
DDT	2 " "
Alkylated naphthalene (PD 544 or Velsicol AR-60)	8 " "
Freon 12	84 " "

From 3 to 5 gm. of total aerosol are used per 1,000 cubic feet of space. The use of residual sprays is a recent wartime development and represents an extremely important advance in the use of insecticides for the control of arthropod-



borne diseases. Residual sprays were made possible by the discovery of DDT and similar insecticides which are toxic in minute quantities and have long lasting properties. Instead of being directed at the arthropod, the residual spray is placed on some surface upon which the arthropod will walk or rest. Thus, instead of the necessity of spraying at weekly, biweekly, or even daily intervals to kill a few mosquitoes which happen to be within a house at the time the spraying is done, a single application of a residual spray on the walls of the house will kill for a three- or four-month period almost every mosquito (and other insects as well) that comes into the house.



From Stierli, Simmons, and Tazewell, Pub. Health Rep. Supp. No. 186, Fig. 4. 12

Fig. 7-1. Spraying a house with DDT emulsion.

This has been the most important single development in malaria control in recent years; it is now possible to bring malaria rates down to extremely low levels, and apparently even to eradicate the disease in rural tropical areas where formerly mosquito control measures were impracticable.

DDT and the other halogenated hydrocarbons are usually applied as residual sprays at the rate of 100 or 200 mg. per square foot of surface. Lindane, the gamma isomer of benzene hexachloride, is said to be effective at 25 mg. per square foot. Several years of experience has shown that for routine use against *Anopheles quadrimaculatus* in the southern United States, a single seasonal application of 200 mg. per square foot is about as effective as two seasonal 100 mg. applications while the cost of the single application is lower. To obtain the 200 mg. dosage, a 5 per cent concentration of insecticide is used; and for a 100 mg. dosage, a 2.5 per

concentration. A 5 per cent solution of DDT contains 5 gm. DDT per 100 ml. solution; one ml., therefore, contains 50 mg., and the 200 mg. dosage requires the spraying of 4 ml. of solution per square foot of surface. Stierli and others (1945) recommend a nozzle which delivers a fan-shaped spray with an angle of 80° and operating at a pressure of 30 to 70 psi. A gallon of the spray, distributed evenly over 100 square feet, represents 4 ml. per square foot; thus the 5 per cent concentration leaves a deposit of 200 mg. per square foot, and the 2.5 per cent spray 100 mg. The nozzle should be held 15 to 18 inches from the wall to produce a swath width of 18 to 30 inches. With a discharge rate of 0.24 gallons per minute, 4 ml. of spray can be applied per square foot if approximately 230 square feet of surface are treated in one minute.

The residual insecticides may be applied as solutions, emulsions, or wettable powder suspensions. The type of building, the surface to be sprayed, availability and cost of materials, transportation problems, etc., will determine the selection of the spray formula. Five per cent DDT in kerosene has been widely used, but as the solubility of DDT in kerosene is low, large amounts of the spray must be transported. An emulsion concentrate simplifies transportation problems. A "standard" emulsion formula for DDT has been given above, but it may be useful to refer to formulae recommended by Stierli, Simmons, and Tarzwell:

SUMMER DDT CONCENTRATE

DDT . . . . .	3 pounds
Xylene . . . . .	3 quarts
Triton X-100 . . . . .	6 fluid ounces

Dilute 1 part of concentrate to 6 parts of water to make a 5 per cent spray.

WINTER DDT CONCENTRATE

DDT . . . . .	2 pounds
Xylene . . . . .	1 gallon
Triton X-100 . . . . .	0.2 quarts

Add one part of concentrate to 3 parts water for 5 per cent spray.

The necessity for the summer and winter formulae is due to the lowered solubility of DDT in xylene in cold weather, and these concentrates were designed to take advantage of the greatest dissolving ability of xylene and the smallest amount of surfactant necessary to produce a satisfactory emulsion. The winter formula is satisfactory for use at temperatures as low as 32° F.

Wettable powders, which can be made into sprays of the desired strength by following directions supplied by the manufacturer, are often especially effective as contact sprays, but as a visible deposit is left on the walls they are more suitable for barns and outbuildings than for houses. However, in rural tropical areas the deposit may not be objectionable in houses, and it may be desirable to take advantage of the greater effectiveness of this type of spray.

Reference should be made to *Entoma*, the yearly directory of insecticides and manufacturers of insecticides published by the Eastern Branch of the American Association of Economic Entomologists, Department of Entomology, University of



Maryland, College Park, Maryland. Sources of supply of insecticides and dispersing equipment may be determined by reference to this directory.

**Insecticide-Resistant Strains of Insects.** An interesting and somewhat alarming phenomenon which has occurred following the widespread use of DDT as a residual insecticide is the building up of housefly populations which are resistant to DDT. In various parts of the world it was observed that DDT was becoming less and less effective in controlling flies. Substitution of another insecticide brought about temporary relief, but liberal use of chlordane and benzene hexachloride was followed by the appearance of strains resistant to these compounds also. In the laboratory resistant strains have been developed to all the residual type insecticides, and the degree of this resistance can be appreciated from the statement by March and Metcalf (1950) that their "super-Bellflower" strain is more than 3,000 times as resistant to DDT as the ordinary laboratory strain, while their "super-Pollard" strain is approximately 10,000 times as resistant to lindane and more than 3,000 times as resistant to dieldrin as the laboratory strain. Furthermore, the DDT resistant strains are also more resistant to related compounds. In building up a resistance to an insecticide, presumably the more resistant individuals survive the ordinary lethal contact; with continuous exposure, a rapid selection of the hardier members continues, and within a relatively short time multiplication of the resistant strain results in a high density of flies that cannot be controlled with the previously effective insecticides. If only a small segment of the fly population is thus affected the resistance may be lost through breeding with nonresistant forms, but with widespread use of the residual insecticides the resistance may spread generally throughout the entire population of large areas. March and Metcalf report that their Bellflower strain lost none of its DDT resistance through 35 generations of nonexposure to DDT, while Bruce and Decker (1950) reared 30 generations of a DDT resistant strain in the absence of DDT without a loss of the resistance in the final progeny.

The mechanism of the resistance appears to be a metabolism of the DDT. Sternburg and others (1950) found that in the resistant flies DDT is rapidly converted to DDE [2,2-bis (*p*-chlorophenyl)-1,1-dichloroethylene]. According to Perry and Hoskins (1950) this detoxification of DDT by resistant flies is largely prevented by treatment with piperonyl cyclonene; thus, there seems to be an interference of the enzymatic process which converts DDT to DDE. DMC [1,1-bis (*p*-chlorophenyl) ethanol] has been shown to have a synergistic effect when used in collaboration with DDT, chlordane and dieldrin against resistant flies.

Other arthropods that have developed resistance to DDT and other halogenated hydrocarbons are bed bugs, fleas, body lice, cockroaches, ticks and mosquitoes. Among the latter are *Aedes sollicitans*, *A. taeniorhynchus*, *Culex fatigans* and *C. tarsalis*. In most parts of the world anti-malarial programs have not been affected by development of DDT-resistant anophelines; however, in Greece *A. maculipennis* and in one area of Indonesia *A. sundanicus*, have shown evidence of resistance. It is not impossible that other vector species may become resistant. Other anophelines have been undergoing changes in behavior patterns as a result of contact with residual sprays in houses. These tendencies may eventually jeopardize the modern approach to malaria control.

**Control Versus Eradication.** The control of arthropods signifies their reduction in numbers to the point where they are no longer annoying or dangerous. Depending upon the numbers of infected and susceptible people, when the diminution of a

or population reaches a certain point, disease transmission stops; thus elimination of the disease does not require the eradication of the vector. However, in order to keep the vector density down to safe levels, continual application of control measures is necessary, and in the complete absence of the disease and a low vector population, this often seems futile. It may be difficult to justify the expenditure of large sums of money for malaria control in places where there is no malaria and apparently no anophelines. The danger in such a situation lies in the fact that with relaxed vigilance the vector population may again increase rapidly to the point where the parasites, made available through relapses or introduction of new cases, can be picked up by the mosquitoes. A happier solution would be the complete extermination of the vector from the country during the enthusiasm of the original campaign.

There have been many demonstrations that disease vectors can be eradicated if enough money and energy is devoted to the project. Through dipping and quarantine, the Texas fever tick has been eradicated from the southern United States. The success of the eradication of *Anopheles gambiae* from Brazil (Soper and Wilson, 1943) has encouraged the belief in the possibility of eradication of other mosquito species as well. Under the supervision of the Pan-American Sanitary Bureau, a concerted attack is being made upon *Aedes aegypti* through most of Latin America, and according to the monthly reports published in the Boletín de la Oficina Sanitaria Panamericana this mosquito appears to be disappearing from this part of the world. *Anopheles gambiae* has also been exterminated in Egypt following its introduction in 1942. It must be noted that both *A. aegypti* and *A. gambiae* are dangerous because of their highly domestic habits, and this also makes them more susceptible to attack, particularly through the use of household sprays. Also, the eradication campaigns against these species were limited to areas into which the mosquitoes have been introduced. The extermination of indigenous mosquitoes, especially those with less domestic habits, is a more complicated problem, for the last specimens remaining in obscure and marginal ecological niches would have to be found and killed. That certain indigenous species at least can be eliminated from circumscribed areas is demonstrated by the results obtained against *Anopheles pseudopunctipennis* in Chile and against *A. darlingi* in coastal British Guiana and in Venezuela. These species, however, are also peculiarly susceptible to attack, the former because of the circumscribed valleys of the Chilean Andes in which all adults and larvae could be reached by the methods employed, and the latter because of its strong domestic habits. One should note that Giglioli (1948), who directed the *darlingi* campaign in British Guiana, carefully points out that in an area such as coastal British Guiana, where there are no natural barriers to the reintroduction of *A. darlingi*, the use of residual DDT will eradicate this species, but that it is a palliative measure that may have to be continued indefinitely. However, as *A. darlingi* is always closely associated with man, and so probably could immigrate only along routes opened by camps, settlements, etc., it may be possible to prevent reintroduction by setting up barriers of residual DDT at certain strategic points along the periphery of the cleared area, and it may not be necessary to continue residual applications within the cleared area itself.

Attempts also have been made to eradicate *Anopheles superpictus* and *A. marovii* from Cyprus, and *A. labranchiae* from Sardinia. Early results were



promising, but it appears that *A. labranchiae* can survive in very small numbers in spite of intensive control procedures. Furthermore, Logan (1950) estimates the cost of the Sardinian demonstration to reach about 12 million dollars by the end of 1950. Eradication, although of great advantage in combating certain especially susceptible species, is not feasible for others. As Soper (1941) said, "One would not recommend eradication of *Anopheles quadrimaculatus* in the United States. . . ."

#### RESUME OF THE ARTHROPODS OF MEDICAL IMPORTANCE

**Order Diptera.** The order *Diptera* is composed of a large number of families of flies, which may be grouped into two suborders: the *Orthorrhapha*, which includes the midges, black flies, mosquitoes, and horseflies, and the *Cyclorrhapha*, which includes the houseflies, stable flies, and tsetse flies. The bloodsucking habit has arisen independently in each of these suborders. The mouth parts of the bloodsucking *Orthorrhaphous* flies consist of two mandibles and two maxillae, which are needle-like and puncture the skin, and two other stylets, the labrum and hypopharynx, which fit together to form a tube through which the blood is sucked into the digestive tract. The hypopharynx possesses a small duct through which saliva containing an anticoagulant is injected into the wound. These six stylets when not in use are kept within the proboscis sheath or labium. The labium ends in two small lobes called labella. In the *Cyclorrhaphous* flies the tissue-piercing mandibles and maxillae have been lost. Most of these flies are not bloodsuckers but feed upon liquid foods which are sucked up through minute openings in two large fleshy pads at the end of the proboscis. These pads are the labella, which have become enlarged to take over the function of food ingestion. A reduction in the size of the labella, accompanied by a strengthening of some prestomal teeth at the end of the proboscis, has made it possible for some of the *Cyclorrhapha* to become bloodsuckers.

**FAMILY HELEIDAE (CERATOPOGONIDAE).** *The biting midges (also called sand flies).* The bloodsucking forms are found in the genera *Lasiohelea*, *Leptoconops*, and especially *Culicoides*. They are very small, but when they attack in numbers they are extremely annoying. They are vectors for the filarial worms, *Dipetalonema perstans* and *Mansonella ozzardi*. The breeding places of the *Heleidae* include fresh and salt-water swamps and marshes, lakes, pools, streams and tree holes. The larvae do not swim free in the water, but burrow down into the mud and debris, or embed themselves in mats of algae. The larvae develop very slowly, requiring from several weeks to as much as several months to become mature, during which time they pass through four stages or instars. In temperate regions the winter is passed in the larval stage. The pupa, which lies quietly at the surface of the breeding place, gives rise to the adult after about five days.

Personal protection against the bites of these flies may be obtained through the use of the newer repellents. Application of 5 per cent DDT in kerosene screens has protected persons within dwellings for about three months. Destruction of the immature stages in the breeding places is difficult because the submerged larvae are not readily reached by ordinary larvicides. However, successes have been reported through the use of 1 pound per acre of DDT in oil solutions, 12 to 1

nds per acre of a 10 per cent DDT dust, and 3 to 5 gallons per acre of DDT solution. Drainage and reclamation of marshes will destroy breeding places.

**FAMILY PSYCHODIDAE.** *The moth flies and sandflies.* The bloodsucking members of this family will probably be referred to in the medical literature as *phlebotomus* for a long time to come, although taxonomists are splitting this large genus into smaller generic units. *Phlebotomus* species are tropical and subtropical in distribution. The adults are readily recognized by the slender, hairy bodies, the long legs, and narrow hairy wings which are held erect over the thorax when at rest. The larvae breed in soil heavily charged with organic matter; there are four larval stages and larval development requires from two weeks to about three months. The pupal stage lasts a week or two.

These insects are responsible for the transmission of phlebotomus fever, Oroya fever, and leishmaniasis. Control of the immature stages is difficult because of the inaccessibility of the terrestrial breeding places. The adults, however, are particularly susceptible to residual insecticides such as DDT. They move in short, darting flights, coming to rest at frequent intervals upon a convenient surface. When approaching a house to procure a blood meal from the inhabitants, the females will come to rest on the outside and inside walls, and are readily killed by short contact with a residual spray. Not only is residual house spraying of DDT extremely effective, but also the application of DDT to stone walls and other proposed selected resting surfaces and shelters may bring about a considerable degree of area control (Hertig and Fairchild, 1948). Dimethyl phthalate is an effective repellent, and has been shown to prevent troops from acquiring phlebotomus fever.

**FAMILY CULICIDAE.** *The mosquitoes.* The true bloodsucking mosquitoes are considered by taxonomists to belong to the subfamily *Culicinae*, and are distinguished from all other flies by the combination of three characters: the type of wing venation, the presence of scales on the wing veins and the long proboscis containing the piercing-sucking stylets. A total of about 2,000 species occur throughout the world, and taxonomists distribute the species among 27 genera, of which the most important are the cosmopolitan *Anopheles*, *Aedes*, *Culex* and *Wyeomyia*; the nearctic and neotropical *Psorophora*; the neotropical *Haemagogus*; the Oriental and Australasian *Armigeres*; and the Ethiopian *Eretmapodites*.

The life cycle of the mosquitoes includes the egg, four larval stages, the pupa, and the adult or imago. Each larval stage is followed by a molt, and when the fourth stage larva sheds its skin the pupa emerges. The time required for development of the immature stages varies according to temperature, food supply, and upon inherent physiological differences between species and genera, but, in general, species of *Anopheles* and *Culex* require two or three days for the incubation of the eggs, 10 to 14 days for larval development, and two or three days for the pupal period. Following emergence, the adult females pass through a preoviposition period of about three days to a week. The entire life cycle, therefore, is usually completed in two or three weeks.

In temperate and tropical regions, breeding may be more or less continuous during the favorable seasons, depending upon the availability of suitable water; there may be several broods a year. In areas where the breeding season is interrupted by winter, the mosquitoes undergo a period of hibernation. In *Anopheles* and *Culex* it is the fertilized adult which hibernates; it passes the winter in a suit-



able shelter. Species of *Aedes* and *Psorophora* hibernate in the egg stage. *Anopheles walkeri* is capable of passing through the winter in the egg stage, and a few species of *Anopheles* and certain plant-cavity breeding mosquitoes hibernate in the larval stage.

The immature stages of all mosquitoes are aquatic; water is essential for the survival and growth of the larvae and pupae, and also for the hatching of the eggs. Eggs of the temporary rain-and-flood-pool-breeding *Psorophora* and *Aedes* are deposited on the damp soil of marshes, the margins of pools, or even in the depressions in the ground where they may remain dormant for weeks or months. Other species of *Aedes* are adapted for breeding in plant cavities or artificial containers. *Aedes aegypti* is the best known of this group, and its eggs are deposited just above the water line where they may dry and remain viable for months. Eggs of *Culex* are thin shelled, and are placed directly upon the surface of the water by the ovipositing female. They must hatch within two or three days, and there is little evidence that they can withstand desiccation. *Anopheles* eggs also are laid directly upon the surface of the water, and ordinarily they also hatch within two or three days. However, they are relatively thick shelled, and there is evidence that they may be quite resistant to dewatering provided they have undergone a suitable period of embryonation and are lying in moist soil. After completing its development within the shell, the larva may wait for free water in order to hatch for as long as three weeks. The ability to delay hatching could explain the sudden appearance of large numbers of larvae along margins of reservoirs with fluctuating water levels; furthermore, it might be of importance to the existence of the species during unfavorable seasons and in submarginal zones of distribution where survival may be accomplished in part through dormant eggs whose presence is unsuspected.

Larvae are unable to withstand prolonged desiccation but pupae are more resistant. Darrow (1949) found a correlation between evaporation rate and mortality of *Anopheles quadrimaculatus* larvae and pupae stranded along the shores of the natural breeding places; even under the most favorable conditions, mortality of the fourth stage larvae was complete after 48 hours. Adults were able to emerge successfully from pupae stranded on moist soil.

Although living in an aquatic environment, the larvae and pupae are air breathers. All larvae except those of the anophelines possess a breathing tube or siphon on the next to the last abdominal segment; at the tip of the siphon there are two spiracular openings, which lead to a pair of tracheal tubes running forward into the body. The anopheline larvae lack the siphon, but the two spiracles are surrounded by four small plates which help the spiracles to maintain contact with the air. In the genus *Mansonia* and a few species of *Ficobia* the siphon is pointed; the larva jabs the siphon into the tissues of plants and thus is able to obtain oxygen without the necessity of coming to the surface of the water.

The larvae are equipped with mandibles and maxillae, with which they ingest small particles of food which are swept into the mouth by means of the mouth brushes. Feeding takes place at the surface film, especially on the part of the anophelines, or along the sides and bottom of the breeding place. Larvae of *Megarhinus* and of a few other species are predaceous; their strong, specialized mouth parts permit them to feed upon the larvae of other species of mosquitoes.

larvae appear to be omnivorous, sweeping into the mouth all particles small enough to be ingested. Dead organic material may be ingested, but perhaps the important source of food is living algae and protozoa. Some authors believe bacteria may be utilized as food, especially by the young larvae, and it has been claimed that even materials in solution or in colloidal form may be of nutritional value. It is evident that the living micro-organisms also furnish essential growth-promoting substances, among which are thiamin and riboflavin; folic acid appears to be necessary for pupation; and additional factors, presumably supplied in nature by the micro-organisms, are necessary.

Almost any type of water is used by the mosquitoes as a breeding place, provided it is quiet, provides reasonable protection from enemies, and contains an adequate food supply. One of the most interesting, as well as an extremely important phenomenon with respect to control of mosquitoes, is the fact that a species or group of species may exhibit a marked preference for, if not an actual dependence upon, a certain type of breeding place. Various factors combine to make available waters either suitable or unsuitable as breeding habitats. Open, shallow waters favor many species, including the majority of the most dangerous malaria-carrying *Anopheles*, but are unsuitable for other species which are found only in densely shaded locations. Inorganic and organic materials determine suitability of the water for many species. It is obvious, therefore, that the larvae have had to undergo a number of physiological adaptations to permit survival in various types of habitat. However, it seems that the proper breeding site is selected by the ovipositing female. Just what mechanisms are involved are not yet clear, although one factor seems to be the visual responses of the females to differences in light intensities at the water surface.

The principal types of breeding places are as follows:

1. *Lakes, swamps and marshes, impoundments*, and the like are especially important as sources of *Anopheles*, as these mosquitoes require quiet bodies of relatively clean water for breeding. In a large body of water such as a lake or impoundment the larvae will not be found in open, windswept areas subjected to wave action; the larvae must be protected from severe water movements as well as from their enemies by vegetation and flottage. One finds the larvae concentrated in certain favored areas which can be spotted readily by an experienced collector. Attempts have been made to correlate the presence of larvae with certain physico-chemical factors, such as pH, dissolved oxygen, nitrogen, food organisms, and so on, but it seems that one of the most important factors in determining the suitability of a breeding site within a large body of water is the physical character of the vegetation as it breaks through the water surface. The margin of the leaf or stem at the water surface has been termed the "intersection line"; this intersection line can be measured per unit of water surface, and it has been shown (Reboom and Hess, 1944) that there is a correlation between the extent of this intersection line and the numbers of *Anopheles* larvae. Plants differ in their ability to create an intersection line; a sparse covering of large lotus leaves produces a low intersection line, and if the water level drops so that only the narrow margins are projecting above the water, the intersection line drops to a small value. Breeding is almost nonexistent. Grasses and mat-forming types of vegetation produce high intersection line values, and breeding in them is most intense.



2. *Streams.* Running water ordinarily is not suitable for mosquito breeding; however, in the Oriental and Indian regions there is a group of *Anopheles*, including the dangerous malaria-carrying *A. minimus* and *A. fluviatilis*, which are especially adapted to breed along the margins of streams, in areas protected by vegetation and other obstructions.

3. *Temporary and semipermanent flood or rain pools.* These are the breeding sites of the *Aedes* and *Psorophora* species whose eggs are deposited by the female in dry depressions on the ground or along the margins of fluctuating waters. The mosquitoes are adapted to go through the larval development rather rapidly in temporary breeding places. If continued rains keep rain pools filled with water, they lose their temporary character and become more or less permanent breeding places of *Anopheles* and other genera. The reason for the increase of malaria in the tropics during the rainy season is the invasion of the innumerable rain pools by the quiet water breeding species of *Anopheles*.

4. *Plant cavities.* The *Sabethine* group of mosquitoes, and a few species of other genera, utilize only various types of water holding plant cavities as breeding sites. Usually, each species is found in only a certain type of habitat, and again the reasons for the selection of a given kind of breeding place for oviposition on the part of the female are of great interest but are unknown at the present time. This type of breeding place includes bamboo internodes, stubs of cut bamboo, bromeliads, tree holes, pitcher plants, fallen coconut husks, palm bracts, and many other objects in which water collects. A few tropical species will even be found in films of water that collect on small fallen leaves in the rain forest.

5. *Fissures and crevices* in rocks along streams furnish breeding sites for certain species which are not found elsewhere.

6. *Artificial water receptacles.* A few species, notably *Aedes aegypti* and *Culex pipiens*, utilize rain barrels, tin cans, vases, and the like.

The points in the life cycle and behavior of the adult mosquitoes that are especially important in their relation to the epidemiology of diseases are reproductive capacity, longevity, host preferences, resting places, and flight habits. Species undergoing a rapid life cycle and which produce abundant eggs are potentially capable of building up populations dense enough to be involved in disease transmission, provided extensive breeding areas are available and also that the females attack the human host in large numbers and live long enough to incubate the infective stage of the disease organism. Only the females are bloodsuckers; the males feed upon plant juices such as nectar of flowers and decaying fruits. There is some preference for certain types of host animals; some species, particularly the genus *Culex*, feed upon birds; *Aedes* and *Anopheles* appear to attack especially domestic animals and man. In a malarious area, the dangerous *Anopheles* species are usually marked by a preference for man that drives them into houses to feed. The habit of entering and remaining in houses for a time is termed "domesticity"; it must be distinguished from "anthropophagy," which refers only to the attractiveness of man to the mosquito. Usually, the malaria-carrying species (*A. gambiae*, *A. darlingi*, *A. sacharovi*, etc.) show a high degree of domesticity as well as strong anthropophagous habit; however, there are a few dangerous malaria vectors, such as *A. bellator* in Trinidad and *A. minimus flavirostris* in the Philippines, which do not rest in houses and may not even feed upon man to any extent in areas

most important to bear this in mind in connection with the use of residual  
s in malaria control.

Mating is thought to take place usually through the mechanism of swarming;  
ever, there is evidence that swarming of the males is not always a precopulatory  
ity. Males congregate in small or large swarms at dusk, usually above an  
t such as a bush; females are believed to fly through the swarm and emerge



From U. S. Dept. of Agriculture.

Fig. 7-2. *Anopheles quadrimaculatus*—male and female.

d with a male. Some species such as the domestic *Aedes aegypti* do not require  
arm. Roth (1948) has demonstrated that males respond to sounds made by  
ying females by attempting copulation; these sounds are detected by means  
e bushy antenna. Males may even be stimulated by sounds made by tuning  
of proper frequencies. Changes in illumination appear to be another factor  
nditioning the males. They become active at twilight; this may be noted in  
n captive colonies as well as in wild populations, and it is sometimes possible  
duce swarming of males and hence promote copulation of *Anopheles* which  
rdinarily difficult to rear in the laboratory by subjecting caged colonies to  
e light of certain intensities.

ertilized females, having partaken of their first blood meal, need from three  
to a week or more to mature their first batch of eggs. Following oviposition,  
female feeds again, and after about two days lays her second batch of eggs,  
which she again feeds. This process is repeated throughout the adult life of  
nsect. There are usually 30 to about 200 eggs in each batch, and a female  
produce a total of a thousand or more eggs. Enough spermatozoa are stored  
e spermathecae following a single copulation to fertilize about all of the  
however, pairing probably occurs several or many times during the lifetime  
e adult.

Most of the adult life of the mosquito is spent in various types of natural  
g places, which include hollow trees, overhanging stream banks, bushes,  
es, and other types of vegetation. The undersides of bridges, culverts, dark



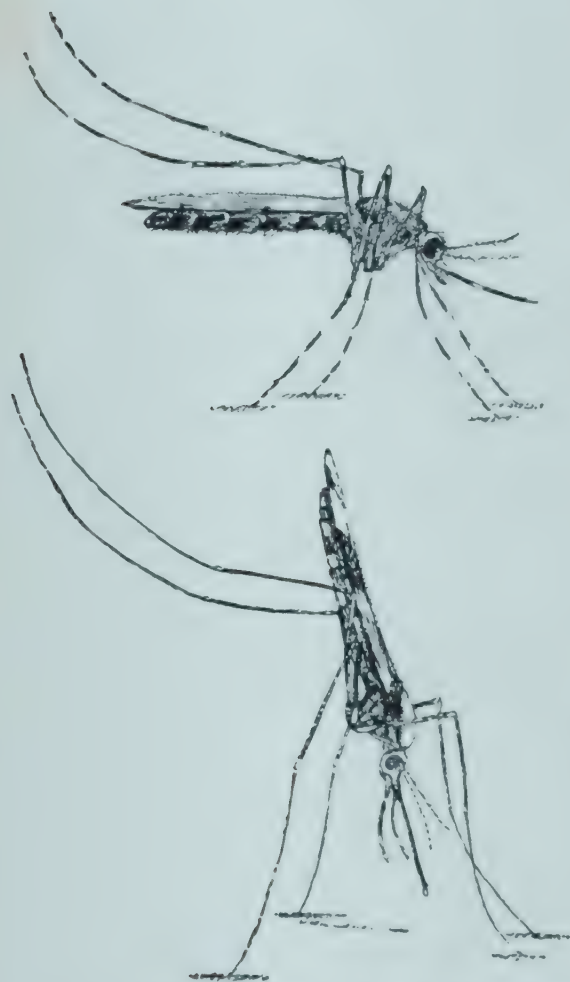
sheds and barns furnish resting places for a few species, particularly among the anophelines.

The female mosquito is faced with the necessity of flying between the breeding waters, the source of blood, and the diurnal resting places, and the distance females can fly from the breeding place determines the extent of the area

included in malaria control operations.

Ordinarily, most anophelines do not fly more than a half mile to a mile, and it has been the practice to control the breeding places of anopheline malaria vectors in a belt of a mile in width surrounding inhabited areas. Anophelines have been observed to fly from 3 to 10 miles under favorable conditions. Such flights might be considered to be in the nature of migrations, rather than representing usual movements, and are probably usually accomplished through a series of short flights. Some culicine mosquitoes, particularly pest species *Aedes*, have been reported to fly from 4 to 40 miles, and to cause severe annoyance within this zone of migration.

The longevity of the adult varies according to species and climatic factors; overwintering females live several months, but during the active season it is probable that females of most species do not survive much more than a month. In laboratory colonies *Anopheles* adults have been observed to live for a month or two. The importance of the adult longevity in disease transmission is illustrated by observations such as those which



From U. S. Dept. of Agriculture.

Fig. 7-3. Resting position of *Culex* (above) and *Anopheles* (below).

indicate that during dry weather malaria transmission is interrupted in parts of India because of the early death of the vector, *A. culicifacies*. According to Hack (1940) quartan malaria is absent from the Nile delta because *A. pharoscensis* is unable to live long enough in this hot, dry climate to permit the slowly developing quartan malaria sporozoites to mature. *A. superpictus* and *A. sergenti* are adapted to desert conditions, and where these longer-lived species occur, quartan as well as other malarias are found.

Some mosquitoes are especially adapted to hot, dry weather. *Aedes* *egypti* is extremely hardy, and may live for months, although it also survives best in a moist atmosphere. For the arboreal *Haemagogus* species a moist environment is actually detrimental; these mosquitoes can be reared best in the laboratory in a dry, warm incubator (Bates, 1947). The metallic coloration of these mosquitoes

be an adaptation to their hot, dry, arboreal environment, and it is interesting to note that species of other genera which have habits similar to those of *Haemagogus* may also have a metallic coloration and are equally long-lived in the adult stage. These mosquitoes breed in small collections of water caught in plant cavities during the rainy season, and the dry season survival of such species may depend on the ability of the adults to live for long periods.

A more detailed account of general mosquito biology may be found in a recent book by Bates (1949).

Mosquitoes represent the most important single group of arthropods of medical interest, as they are responsible for the transmission of malaria, filariasis, yellow fever, dengue, the encephalitides, and Rift Valley fever. They are serious pests, cause great economic loss through nondevelopment of badly infested areas and annoyance and death to livestock.

**Mosquito Control.** The control of mosquitoes has undergone great improvement since the advent of the more toxic and residual insecticides. Mosquito control may be said to have three objectives. First, there is pest control, in which all the species in an area which annoy man are attacked through blanket measures. Second, there is species control, the purpose of which is to attack only the vector species. This concept came into being especially through the demonstrations that only certain species of *Anopheles* were important as malaria vectors, but more recently the use of residual insecticides in houses has caused a de-emphasis of this approach. The third objective, eradication, was discussed above.

Defensive measures against mosquito attack involve the wearing of protective clothing, the use of the newer repellents, and mosquito proofing of houses. In the United States 16-mesh galvanized screen wire is satisfactory for screening, but in tropical areas, particularly near the seacoast, copper screening is more lasting. Larger mosquitoes such as *Aedes aegypti* and *Anopheles bellator* are able to pass through 16-mesh screen and where protection is desired from such small species, finer mesh screen may be necessary. Mosquito proofing of rural houses requires not only the screening of windows and doors, but also the elimination of all cracks and crevices in walls, floors and ceilings by papering with a heavy kraft paper or asphalt roofing paper, the covering of larger holes with boards or strips of tin, and the use of a removable screen before fireplace openings.

**DESTRUCTION OF MOSQUITO LARVAE.** Of the many natural checks on mosquito larvae, one of the most effective is the predatory action of fish, and the best known of these predators is *Gambusia*. These fish are highly efficient in seeking and feeding upon the larvae; they reproduce rapidly and have adapted themselves to various types of breeding places into which they have been introduced in many parts of the world.

Naturalistic larval control measures include the planting of dense shade plants along the banks of streams, the periodic flushing of such streams through the use of a series of dams equipped with flood gates or automatic valves, intermittent irrigation of rice fields, and the increase in salinity of brackish waters through the use of dikes and tide gates. The presence of domestic animals in houses will divert weakly anthropophagous anophelines such as *Anopheles tritaeniorhynchus* and *A. messeae* from the human hosts. In the United States, perhaps the most effective single naturalistic control measure has been the water man-



agement program of the Tennessee Valley Authority in its system of huge reservoirs. Malaria control is part of the overall plan of the reservoir. Prior to impounding, the shoreline of the proposed reservoir is cleared of vegetation, and following completion of the dam, the reservoir should be filled during the winter months, which would permit stranding and removal of flotsam before breeding begins. The ideal program for water level management includes a flood surcharge with the water up to the top of the gates during the nonbreeding winter season for the purpose of stranding all flotsam and drift; a drop in water level to the normal operating level in the early spring, at which time very little breeding takes place, a period of cyclical fluctuation of the water level during the moderate breeding of the early summer, in which the water is raised and lowered approximately a foot at weekly or 10-day intervals; and a weekly cyclical fluctuation combined with seasonal recession during the heavy breeding season of late summer. The purpose of the seasonal recession is to keep the maximum pool level constantly retreating from the encroaching mat of marginal vegetation, while at the same time the cyclical fluctuation continues to operate in its destruction of those larvae that have managed to become established.

The actual mechanism involved in the killing of the immature stages by fluctuating water levels are twofold. From Darrow's (1949) observations it seems evident that most of the larvae and pupae are drawn by the receding waters out of the protection of their breeding sites into open water, where fish and other predator wave action, and possibly lack of food organisms, combine to eliminate them. In vegetated areas and with slow draw down, many larvae and pupae are stranded on the shore, where most of them fail to survive an eight-hour exposure. Death is due to either the direct effects of desiccation or to the activity of insect predators.

**DRAINAGE.** According to Herms and Gray (1940), drainage is "in most cases the most effective antimosquito measure since it robs the mosquito of its breeding place and thus affords the best possibility of complete and relative permanent abatement." Drainage may be effected through surface ditches, which connect low-lying areas with a main drain. Such ditches may be constructed with hand labor or with special ditching machinery such as dragline excavators, and sometimes by blasting simultaneously a series of dynamite charges. Surface ditches must be maintained, or they themselves become mosquito producers. They must be kept free of vegetation and other obstructions; scouring by heavy run off may cause water-holding depressions to form along the bottom of the ditch; or banks may cave in. It may be more economical to line the ditch with concrete or masonry inverts. Subsoil drain tiles may be used effectively in many places; they have the advantage of not in themselves creating breeding sites. Occasionally, it is possible to employ vertical drainage for a body of water trapped over a bed of hard pan. Control of breeding in extensive coastal marshes may involve reclamation employing dikes, drainage ditches, tidal gates, and pumps. Sometimes areas that cannot be drained may be filled, or a swampy area may be deepened, cleared, and transformed into a nonbreeding recreational pond.

All of these engineering measures require technical knowledge outside the scope of this book. A trained engineer is an essential member of a competent malaria and mosquito control team, wherever problems are of such a scope that environmental sanitation is necessary. All members of the team must have a thorough knowledge

the biology of mosquitoes; without it, control may be purposeless or even detrimental. For example, as noted above, clearing and impoundment of some swampy marshy areas may convert a breeding area into an open water pond in which larvae cannot survive; on the other hand, thoughtless clearing of a shaded pond may make the water unsuitable for harmless, shade-loving species of mosquitoes, but permit the breeding in tremendous numbers of sun-loving, dangerous malaria vectors.

**LARVICIDES.** Larvicides must be resorted to for control of breeding in areas amenable to naturalistic measures or where the latter are not economically feasible. Larvicidal oils and Paris green have largely been supplanted by the newer, more toxic insecticides and, of these, DDT has been the most widely used. A dosage of 0.1 to 0.2 pounds DDT per acre as a dust, or 0.05 pound DDT in solution may be used without great danger to fish or other aquatic organisms in a lake or pond, particularly if applied only to the marginal and vegetated areas in which breeding occurs. Frequently, 0.1 pound of DDT per acre in oil solution is used, but this heavier dosage should be used only after due forethought to the possible effects upon fish and wildlife. Where the latter do not constitute a problem, 0.1 pound per acre may be considered as the standard dosage.

For use as a larvicide, a 1 to 5 per cent solution may be made in kerosene or fuel oil. In order to distribute the DDT at the rate of 0.1 pound per acre, only one quart of the 5 per cent solution is required. Although this may be done with difficulty from an airplane, for hand distribution it is simpler to spray a gallon of the 5 per cent solution. Where special precautions are necessary to avoid killing of fish, the gallon of spray should contain 0.05 pound DDT. Ferguson and others (1947) selected No. 2 fuel oil as the solvent, and state that the larvicidal effectiveness was increased by the addition of a spreading agent, such as 0.5 per cent kerosene. In 1956. The larvicide may be distributed effectively by means of a knapsack sprayer equipped with a nozzle that delivers a fine mist spray. The operator treats the breeding waters by walking along the shores or through the breeding place at an angle to the wind and allowing the mist to drift with the wind across the water. The pressure in the sprayer should be from 30 to 50 pounds, and the operator should proceed at the rate of about 75 feet per minute. Moderate winds will distribute the mist across the water for about 30 feet, and so the operator should treat the entire breeding place in 30-foot swaths. This may be done on foot, or, if the water is too deep, by boat. The advantages of *Anopheles* control by this method over the older use of oil larviciding, which often required several gallons of oil, heavy equipment, and storage and transportation of large quantities of oil, are obvious.

More elaborate equipment may be necessary for control of extensive breeding areas, and various types of spray rigs are available on the market, from power sprayers to fog machines. Airplane application of insecticides, either as sprays or thermal aerosols, has simplified control of extensive breeding areas not accessible by other means. Various types of sprayers have been adapted for both civilian and military combat planes, including the Husman-Loncoy unit, the breaker-bar sprayer, and exhaust generators. The 5 per cent solution in fuel oil may be sprayed from aircraft, but it is said that the addition of 10 to 20 per cent by volume of motor oil (S.A.E. 10 to 80) improves the efficiency of the larvicide. With an exhaust



generator, a 20 per cent solution of DDT is used, and liberated through an extension of the exhaust stack, where it is broken up into fine spray and aerosol particles. The types of exhaust generators and effectiveness of the aerosols and sprays produced are discussed by Krusé and his associates (1946; 1949).

For culicine larvae, heavier dosages of DDT, up to 0.4 pound per acre, may be necessary. In some areas, especially where larvae have become resistant to DDT, it is advantageous to use other larvicides. Good results have been obtained with the application of 0.1 pound per acre of lindane, the gamma isomer of BCH, dieldrin and heptachlor. In small ponds, burrow pits, etc., where fish and other wildlife do not present a problem, application of three pounds of DDT or one pound technical BCH will control larvae for several weeks. One pound of dieldrin per acre will prevent breeding for one to two years. Larvicides are usually applied as oil solution, but for heavy dosages emulsions are used. Better penetration through vegetation is possible with the use of granulated insecticide such as coarse tobacco stem dusts or clay pellets which have been impregnated with DDT, BCH or dieldrin.

For control of *Aedes aegypti*, vases and other small water containers may be treated with a saturated solution of DDT in 95 per cent ethyl alcohol dispensed with an eye dropper at the rate of one drop to a quart of water. Fire barrels treated with a 35 per cent xylene emulsion concentrate at the rate of about 1 ml. to 50-gallon barrel were kept free from larvae for four months or more.

**DESTRUCTION OF ADULT MOSQUITOES.** The development of the stable, residual type insecticides has made possible a new principle in the control of mosquitoes. Formerly, greatest promise of success lay in an attack on the larvae, as they are confined to an aquatic environment. The adults, on the other hand, leading an aerial existence, and resting in out of the way places, cannot be reached by the ordinary insecticides, and even though trapping, hand catching, and spraying of dwellings might kill off large numbers, enough females escape to permit breeding to continue undiminished. Systematic house spraying with pyrethrum to kill adult mosquitoes has been very effective in stopping transmission of malaria, but it usually had little effect upon the density of the mosquito population.

The effectiveness of the *residual insecticides* lies in the fact that a poisonous coating may be placed on the walls and ceilings of dwellings and other shelter which will continue to kill almost every adult which comes to rest in these places for weeks or even months. It is important to understand the habits of the adult of the species against which the residual spray is to be used. Most anopheline which are disease vectors enter houses to feed upon man and, after the blood meal, they usually rest for a time upon the wall or ceiling of the dwelling. Such species are susceptible to a residual spray, and this is especially true of the most highly domestic and hence most dangerous species, such as *A. darlingi*. Residual spraying of houses not only immediately stops practically all disease transmission by the highly anthropophilic and domestic species, but because the females enter houses by preference, the residual spray reduces and may even stop larval breeding. The Giglioli has been able to eradicate *A. darlingi* from coastal British Guiana through the use of *residual DDT in houses*. Most anophelines are not so strongly attracted to man, but feed indifferently upon man or his domestic animals. Nevertheless,

ual spray in houses is highly effective in preventing disease transmission by individuals which enter houses to feed upon man. Trapido (1946) describes action of residual DDT against *Anopheles albimanus* as manifesting itself in ways: (1) in the marked reduction of adults in houses for approximately months; (2) in the activation and consequently the prevention of feeding by individuals that entered the houses by passing through the interstices between pane walls; and (3) by the high mortality after 24 hours of those individuals did manage to obtain a blood meal. After four months, in the thatched roofed, sided dwellings of these tropical, Panamanian villages, the residual deposit prevented most engorgement from taking place, but the mosquitoes began to ve the 24-hour period of observation. In these conditions, treatment at four h intervals is indicated. Repeated four-month treatments were progressively ive, and Trapido states that in the third four-month post-treatment period the ction of blood-engorged *Anopheles* surviving 24 hours reached the impressive e of 99.9 per cent. If sheds, barns, and other resting places are treated, there be a marked reduction in density of even moderately domestic species. There few dangerous, highly anthropophilic species which cannot be controlled by ual DDT in houses. Thus, in Trinidad, it has been shown (Rozeboom and l, 1942) that the malaria-carrying *Anopheles bellator* feeds mostly out of s, and thus it would not come into contact with the walls of houses. It is of est to note that in southern Brazil this species does enter houses in large num- Although it was feared that *A. minimus flavirostris*, which does not rest in es, might not come into contact with a residual deposit (Smith and Dy, 1949), has been highly successful in the control of this species in the Philippines. Adult mosquitoes may be killed as they rest in woods, or other natural shelters, hgh the use of aerosols or sprays, applied either with hand sprayers, power vers, thermal aerosol machines, or by plane. Such measures are often useful otecting military or other personnel who must remain in the infested areas.

**Family Simuliidae. The black flies.** The adult black fly is characterized by its , stout body, hump-backed thorax, and broad, membranous wings. These ts are cosmopolitan in distribution, and are abundant in the vicinity of swiftly ng streams, which are the typical breeding habitat of most species. The eggs, sited on grass, twigs, or other objects in the stream, hatch into larvae which h themselves to rocks, logs, or plant stems and leaves in swiftly running r. The larvae require four or five weeks to mature in the summer months. mature larva spins a silken cocoon, within which it pupates. This stage lasts days to about two weeks, and the adult emerges in a bubble of air by which e carried up to the surface of the water. The adults are strong fliers; the females y day and seldom enter buildings to feed. When especially abundant, they only cause great annoyance through their attacks on man and domestic animals, they may cause considerable economic loss by killing livestock. They are also rs of *Onchocerca volvulus*.

Control of black flies through an attack on the immature stages has been difficult use of the inaccessibility of these stages at the bottom of streams. Preliminary rvations have shown that they can be killed with DDT emulsion, and in obi, Garnham and MacMahon eradicated black flies from a 65-square mile area



through liberal use of DDT emulsion in streams. Too high a concentration of DDT will kill fish, and as trout streams are excellent breeding places of black flies, an insecticide must be used with caution. Gjullin and his associates (1949) tried several insecticides in various formulations against blackflies in Alaska, and found that DDT in acetone was the material of choice as it killed the larvae at a concentration of 0.3 parts DDT per million parts of water but was not lethal to rainbow trout at 30 p.p.m. DDT in fuel oil or kerosene was about as effective as the acetone solution, and the authors suggest that this is the most practical formulation. The larvicides are placed in the stream at a turbulent spot in order to insure mixing; a board used as a deflector under the outlet, or the use of multiple outlets will permit better mixing. Many streams in mountainous areas are not accessible by ordinary ground equipment, but the authors showed that a 20 per cent DDT spray applied by airplane at the rate of 0.2 or 0.1 pound per acre was highly effective. The planes flew at right angles across the streams at 50 to 100 feet altitude, and four 100-foot swaths at the 0.2 pound per acre dosage caused all larvae to detach for a half mile downstream.

Residual insecticides may be of some use if applied to vegetation in which adults rest. The dusting of bushes, shrubs, and other vegetation with DDT dust at the rate of 15 pounds of DDT per acre will provide limited area protection. Aerosols and sprays will also kill resting adults.

The new repellents will protect the user from attack for several hours; they may also be used on domestic stock at the rate of about 150 ml. per animal.

**Family Tabanidae.** *The horseflies and deer flies.* The adults are large, robust insects with strong powers of flight. They are active by day and attack man and animals indiscriminately. The larger, darker colored horseflies are associated with animals, and mechanically transmit certain animal parasites such as anaplasmosis and surra, while man is attacked especially by the smaller, more brightly colored deer flies. The latter are responsible for transmission to man of the filaroid *Loa loa* and tularemia.

Most of the tabanids lay their eggs in a packet on leaves or twigs above water at the edges of ponds or streams. The larvae hatch from the eggs and drop into the water, where they sink to the bottom and burrow into the mud. From here during the course of their life, they work their way through the soil away from the water, and eventually come to lie beneath the surface of dry ground. Older larvae of *Chrysops discalis* rise to the surface of the water at night, and are carried by wind and currents towards the shore. Larvae of *T. lusiophthalmus* molt eight times before winter sets in; they hibernate as mature larvae, and in the spring the pupa is produced by the ninth molt. After about two weeks the adult emerges from the pupal case. Although tabanids are usually associated with water, larvae of some species may be found in many purely terrestrial situations. In New York the important pest species *T. quinquevittatus* breeds in moist but not wet soil of pastures and meadows. The strong larvae are predaceous, and feed upon insect larvae, earthworms, and similar kinds of prey.

Control of tabanids is difficult because of the inaccessibility of the immature stages in the soil. Some success has been reported through the use of an airplane to spray oil solutions of DDT at the rate of one pound DDT per acre of stream line; 1 per cent by weight of aluminum stearate added to the spray prolonged

dual effect and increased coverage. Some reduction in horsefly and deer fly abundance has been noted following thorough treatment of hides of range cattle with sprays of DDT, BHC, chlordane, and methoxychlor. Roth and Lindquist (48) were able to trap thousands of ovipositing females of *C. discalis* by smear- a nondrying adhesive on boards set up on end along the shores of a lake. Large numbers of females were attracted to such stakes or other objects when they were placed some distance away from the sedges which formed the natural oviposition site.

**Family Rhagionidae. The snipe flies.** Although not concerned with disease transmission, the snipe flies should be mentioned because a few species are blood-suckers. They somewhat resemble the horseflies.

**The Muscoid Diptera.** This is a large group of *Cyclorrhaphous* flies, and includes several closely related families which are of medical importance; the *Muscidae* (housefly, stable fly, tsetse flies, etc.), the *Calliphoridae* (the blowflies), and *Sarcophagidae* (the flesh flies). In this group are also the ox warbles, the eye bots, the sheep head grub; also, there are two more distantly related families which must be considered, the *Drosophilidae* (fruit flies) and the *Chloropidae* (biting flies or eye gnats). The taxonomic relationships of this large group of flies are complex and difficult; for our purpose it is convenient to consider first the nonbiting forms, second the bloodsucking forms, and finally the species with parasitic habits.

**THE NONBITING FLIES.** The common housefly, *Musca domestica*, may be used to illustrate the general biology of the nonbloodsucking muscoids. This species is cosmopolitan in its distribution, and is represented in much of the Old World by the subspecies *vicina*. The female fly deposits about 100 to 150 eggs in a batch on a suitable breeding medium. A female fly may deposit several to as



Fig. 7-4. Housefly (*Musca domestica*) using proboscis in the act of eating sugar.

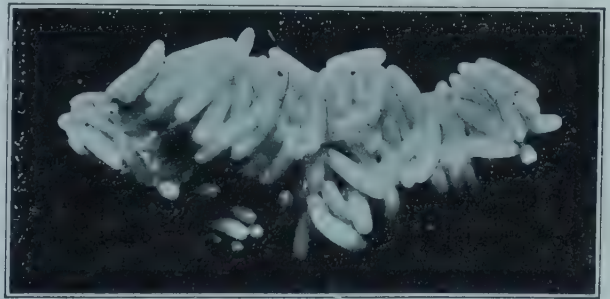


Fig. 7-5. Eggs of housefly as laid in a mass.

as 20 or more batches, so that the total output may be over 2,000 eggs. Incubation period varies with the temperature, ranging from 6 to 12 hours. The wedge-shaped larva tapers to the rudimentary head, which is armed with a pair of mouth hooks. There are three larval stages, and it takes about a week for the larva to complete its development. At this time the larva crawls away from its breeding medium to a drier environment; then the larval skin shortens, folds up at the ends, and hardens to form the puparium, which is dark brown in color. Within the puparium pupation takes place and the imago is formed. The pupal period lasts three or four days. When the adult is ready to emerge, the body



fluids are forced into the head, resulting in the formation of a large bubble-like ptilinum which forces off the anterior end of the puparium and permits the fly to escape. The ptilinum then retracts. Copulation takes place on the first day after emergence, and the female may begin to lay eggs on the third day after emergence. The entire life cycle, therefore, under favorable conditions, may require as little as 12 days, and with the high reproductive potential, tremendous fly populations may be built up within a very short time. In temperate regions the flies become most abundant during the warm months of the year; in the tropics they seem to be especially prevalent after rains. Overwintering appears to take place as full grown larvae, but in protected places, such as barns or other buildings where there is some heat, reduced breeding may continue throughout the cold season.



Fig. 7-6. Larvae of housefly.

The housefly, and the related species of blowflies and flesh flies, are of medical importance because of their feeding habits and because of their strong powers of flight, which makes it possible for them to transport mechanically pathogenic organisms from fecal material directly to man or to food about to be ingested. The adults feed upon all kinds of materials in solution or in suspension, which are sucked up through small openings in the large, fleshy labella at the apex of the proboscis, and if the insect is feeding upon feces passed by a diseased person, bacteria and even ameba cysts may adhere to the labella or actually be taken into the gut or esophageal diverticula. When replete, flies have the habit of regurgitating and the vomit droplets may contain organisms that had been ingested and were adhering to the labella. Bacteria may be passed off with the feces; they may also be transported by adhering to the legs or the external surface of the fly's hairy body.

The adult houseflies and blowflies may travel for long distances; this is particularly true of blowflies, which range widely and invade an area in a short time if attractant food and breeding materials become available. Houseflies are not likely to range afar, but remain within the neighborhood of the breeding place unless forced out by population pressure. Thus city dumps, poorly sanitized food processing plants, dairies, etc., may be so highly infested that they will be the source of houseflies for an entire community.

The characteristic breeding places of the housefly are deposits of fecal material. Manure pile has always been the principal source of houseflies in rural areas, other decomposing organic material, especially high protein stock feed allowed to become moist, may also support breeding. Blowflies are essentially scavengers, feeding in decomposing carcasses, but they will breed as well in other decomposing material of animal origin. Important sources of houseflies, blowflies, and related species in urban areas are garbage dumps, garbage cans, dog feces, scraps of food and debris about restaurant loading platforms, greased soil around fat-rendering plants, abattoirs, privies, and stables. The importance of understanding the nature of the breeding places in areas where fly infestation is a problem, lies in the fact that treatment of buildings with DDT or other residual sprays will kill off only a small percentage of the flies being produced.

The resting habits are another aspect in the biology of the adult flies which is of importance in control procedures. The flies are inactive at night, and treatment of nocturnal resting places may be a highly effective means of attack. Scudder (1919) observed that in summer, houseflies as well as blowflies rest out of doors at the feeding and breeding places, on twigs at the end of low-hanging branches, on weeds, fences, wires, and edges of buildings, in locations where there is protection from the wind, and above ground level but not above 15 feet in elevation. In cooler weather, houseflies prefer to rest inside buildings, while the blowflies continue to rest out of doors. In buildings, houseflies rest on edges of projecting boards, eaves, and other prominences.

Disease organisms which can be transmitted by the housefly and its nonbiting relatives are those which are picked up by the insects in the dejecta, or in blood from wounds or exudations from sores and mucous membranes. In unsanitary surroundings, particularly under military or internment camp conditions, where large numbers of flies moved freely between unprotected food and uncovered fecal deposits, outbreaks of typhoid and dysentery have been attributed to the transfer by flies of bacteria from the feces to the food. Watt and Lindsay (1948) reported a significant reduction in the incidence of *Shigella* infections as a result of thorough residual treatments. It has also been reported that intensive malaria control campaigns through the use of DDT have not only reduced malaria and the mosquitoes, but have reduced intestinal infections and infant mortality, presumably through the destruction of flies. Recent work has shown that poliomyelitis virus, deposited with the feces, may be picked up by flies. Naturally infected flies have been found in localities where poliomyelitis epidemics were occurring. *Entamoeba histolytica* may be fly-borne under suitable conditions. Fly transmission of all of these infections is more or less accidental, and can take place only where lack of sanitation permits high fly densities and access to feces. The species of *Chloropidae* belong-



Fig. 7-7. Puparium of housefly.



ing to the genera *Hippelates* and *Siphunculina* may become extremely annoying by crawling over the skin to feed upon the sweat and exudations from sores and mucous membranes. The mouth parts are armed with a specially adapted rasping apparatus to better enable the insect to obtain its food. These small gnats thus are capable of mechanically transmitting eye infections, and have been associated with outbreaks of pinkeye, "Naga sore," and epidemic conjunctivitis; they have also been shown to transmit yaws.

In the control of the housefly and its allies, great benefit has resulted from the use of DDT and other residual insecticides. DDT, applied at the rate of 200 mg. per square foot, remains toxic to flies for three months or more, provided the surface is protected from weathering, accumulation of dust, and the like. Scudder (1949) recommends a 2.5 per cent spray on rough unpainted surfaces such as are found in barns, a 5 per cent spray on painted or plaster surfaces, and a 7.5 per cent spray on smoothly finished surfaces in restaurants and homes. The idea is to apply the spray so as to thoroughly wet the surface without run-off.

Scudder also emphasizes the importance of treatment of the nocturnal resting places out of doors, as the flies are inactive for several hours and hence the residual insecticide would be much more effective than it is indoors on the surface of diurnal resting places where the active flies come into contact with it only briefly. The wettable powders are more suitable for use in spraying outdoor resting places, as they are not so harmful to vegetation as are oil solutions, and appear to adhere better to vegetation. It has also been found that the addition of an adhesive consisting of 10 per cent pine gum rosin to the 25 per cent DDT-xylene emulsion concentrate will increase the duration of an emulsion residual on exterior surfaces.

Benzene hexachloride, chlordane, methoxychlor, chlorinated camphene, DDT and dieldrin have all been found to be more or less effective as residuals for fly control. However, there is serious doubt as to the continued effectiveness of the chlorinated hydrocarbons because of the development of resistant strains of flies.

Space sprays may be used by the householder for temporary relief. They may also be used in community fly control; in this case whole areas are sprayed from an airplane or fogged with a ground aerosol-producing machine. Kruse (1948) states that satisfactory urban control without staining damage may be obtained with sprays having a minimum mass diameter of 200 microns applied from an airplane flying at 100 to 150 feet altitude. He recommends a 30 per cent solution of DDT in Velsicol AR-60, applied at the rate of 0.5 pound of DDT per acre.

Regardless of the effectiveness of various insecticides in reducing fly density and even in reduction of enteric infections, experienced observers have been emphasizing the importance of *sanitation* as the real solution to the fly problem. Elimination of fly breeding in city garbage dumps, which may produce enough flies to infest an entire municipality, could be achieved by proper sanitary garbage disposal methods. Other recommended measures are the picking up of dog feces by individual dog owners, provision of adequate garbage containers by householders, periodic cleaning of the containers and wrapping of garbage to prevent accumulation of garbage sludge at the bottom of the cans, and elimination of privies. W. outlines the following steps in a program designed to control fly-borne diseases:

1. Preliminary survey of the problem area to determine whether flies are actually involved in dissemination of disease.

2. Planning of basic sanitation methods, including garbage disposal, disposal of feces, proper care and feeding of domestic animals, and supervision of waste disposal from industries.

3. While the sanitation program is getting under way, the use of insecticides to reduce the active fly population. This may be effected by the use of residual sprays, discussed above, or through the use of space sprays, which, in large operations, may be sprayed from airplanes or by means of the ground spray machines. During the period larvicides, such as orthodichlorobenzene, may be used, but steps must be taken promptly to eliminate the conditions which permit breeding in the breeding areas. Watt concludes that the major emphasis should be "on an enduring preventive program rather than a temporary palliative measure."

For control in rural areas, proper *manure disposal* is essential. Under certain circumstances manure may be burned, stored in special vats until it has matured, stored in compact heaps covered over with a tarpaulin or tarred paper. Manure is a necessary fertilizer, and ordinarily cannot be destroyed; however, as Scudder points out, the manure pile is "incompatible with modern dairy sanitation." Daily removal would help if it were possible for the farmer to accomplish this; temporary storage of three or four days will probably not reduce breeding markedly. If manure must be stored, some reduction in breeding is obtainable through the use of larvicides. Those used have included hellebore at the rate of 0.5 pound per bushels of manure, and powdered borax at the rate of 1 pound to 16 cubic feet of manure. More recently, the chlorinated insecticides have been used, but Bruce and Hoyer (1950) recommend the use of larvicides not chemically related to a residual which may be employed in the same area, in order to delay the building up of resistance of the insects. An emulsion containing 2 to 4 per cent chlordane, applied at a rate of 50 to 100 mg. of the toxicant per square foot of surface, is said to give good results. Good kill of larvae has been obtained through the use of 20 gm. of dichlorobenzene or 25 ml. orthodichlorobenzene per square foot of surface. Repeated in two to four days, these dosages may be reduced respectively to 15 gm. per bushel. These materials are also good ovicides. Larvicides may also be applied to garbage, and cadavers. If garbage is fed to hogs, chlordane and similar compounds cannot be used.

Various types of fly traps may give some local relief from annoyance; screening of houses is an important protective measure; protection of foods by screens, nets, and the like is highly desirable.

**THE BITING MUSCOID FLIES.** The bloodsucking *Muscidae* include several important parasites of domestic animals, such as the horn fly and stable fly or "dog fly." The latter breeds in decaying vegetable matter such as that found at the bottom of manure racks, accumulations of seaweed, and the like, and at times breeding may be so heavy that the fly density reaches outbreak proportions. The insect attacks man and may cause extreme annoyance. Fortunately, this ubiquitous fly is not a carrier of organisms pathogenic to man. Related to the *Muscidae* are the commensal parasitic *Pupipara*, which live upon mammals and birds. The wingless sheep tick "tick" is a member of this group.

The most important of the biting *Muscidae* are the *tsetse flies* of tropical Africa, which are vectors of the trypanosomes which cause Nagana in animals and sleeping



sickness in man. They are somewhat larger than the house fly, and are recognizable by the bayonet-like proboscis projecting from the lower margin of the head. The life cycle of the tsetse flies is especially interesting in that the larva undergoes its develop-



Fig. 7-8. Stable fly (*Stomoxys calcitrans*).

Left, adult fly; right, head showing proboscis. (After Brues.)

ment entirely within the body of the female. One larva is matured at a time, and the female may produce a total of 8 to 10 larvae. The larvae are dropped in a suitable sheltered habitat, where the soil is dry, shaded, and loose enough so that the larva can burrow through it. Within a few hours after having been dropped, the larva has

penetrated into the soil for a depth of an inch or more and then pupates. The adults also require a suitable habitat in which to reside where they will be protected from heat and drying; larvae and adult requirements are found, depending upon the species, within certain types of bush or thicket. The bush in which survival is possible through the unfavorable hot, dry season is recognized as the "winter habitat" of the flies; during the rains when the vegetative cover increases, the flies are able to spread out into areas which ordinarily would be unsuitable. Areas



Fig. 7-9. Tsetse fly (*Glossina palpalis*).

infested with the flies are known as fly belts; these fly belts contract or expand with the seasons. The fly belt of *Glossina palpalis* and *G. tachinoides*, the important vectors of Gambian sleeping sickness, is a narrow one comprised of the wooding forest along the banks of streams or the shores of lakes. *G. morsitans* and *G. swynnertoni*, the important vectors of Rhodesian sleeping sickness and Nagana, are found in the open savannah country, where, although indifferent to the presence of water, they

and in the shelter of certain types of vegetation. The fly belts inhabited by the species may be very small or very extensive, covering thousands of square miles. Within the true habitat breeding occurs, but young, recently fertilized females driven by hunger out of the dense cover of the true habitat into more open country, where better visibility enables them to find animals upon which to feed. These hungry females will also attack man, although the game species, such as *G. morsitans*, prefer to feed upon animals. *G. palpalis* and *tachinoides*, in their riverine habitat, are more closely associated with man and are able to exist with only man and domestic animals as sources of blood.

Because of the advanced larviparous mode of reproduction, control of the tsetse flies has been difficult but, nevertheless, considerable success has been attained in the control of the human trypanosomiasis at least. Aside from the use of chemotherapy and chemoprophylaxis and removal of populations from endemic zones, the measures employed that have been most successful are the clearing of vegetation from the true habitat, catching of adults, and destruction of game. Clearing operations may be limited to small protective clearings at river crossings, near villages, trading sites, and the like to prevent contact between the riverine tsetse and people who must enter this habitat, and aggressive clearings, by which tsetse are eradicated from large blocks of country by drastic removal of vegetation. Through discriminative clearing of only the vegetation forming the true habitat, even the widespread savannah species may be attacked effectively; in East Africa, clearing, resettlement, and farming operations combine to free large tracts of country from *G. morsitans* and its allies. A combination of block clearings along rivers and routine handling by teams of fly boys working through the uncleared areas along paths parallel to the streams has been found to reduce greatly the chances of infection with Gambian sleeping sickness. Adult tsetse hunt mainly by sight, and some species can be fooled with the rudest of decoys; many types of traps, of which the best known is the Harris trap, have been devised to catch adults. The systematic destruction of game, which serves as the source of blood for the savannah-inhabiting species, has been credited with freeing large areas of East Africa from *G. morsitans*. *Callidipes* is less affected by game destruction, as it will feed upon small animals and insects, while the riverine *G. palpalis* and *tachinoides* have been shown to be capable of survival in West Africa in areas in which game has long since been exterminated. Recently, control has been attempted through the use of DDT and benzene hexachloride; these insecticides were sprayed from airplanes, or applied to the vegetation of the habitat, or applied to the hides of cattle. Great reductions in fly densities occurred in the treated areas, but up to the present time the use of these insecticides has not given the hoped-for results.

**Myiasis.** The term myiasis refers to the parasitism of man and animals by fly larvae. All stages in the development towards parasitism may be observed among the *Corrhaphous* fly larvae. Most of them are free living, breeding in decomposing vegetable or animal matter; others occasionally invade the digestive or urinary tract accidentally, where they may exist for a short time; and still others infest wounds where they feed upon exudates and necrotic tissues. The latter are larvae of blow-flies and flesh flies, which ordinarily breed in decaying carcasses. Some of the blow-flies also breed in the wool of sheep and so cause serious economic loss. The true



or obligate parasites invade living tissues of man and animals, and are found either beneath the skin, in wounds or body openings, or in the digestive tract.

Larvae which live beneath the skin cause cutaneous myiasis. The ox warble (*Hypoderma*) cause large cysts to form on the backs of cattle, and in each cyst a single larva completes its growth. In tropical America, similar cysts are produced by the larvae of *Dermatobia hominis*, which attacks both man and animals. The female of this interesting insect glues its eggs in small packets usually to a mosquito when it has captured. The larvae are carried to the host by the mosquito when it seeks a meal of blood. In Africa, the eggs of the tumbu-fly, *Cordylobia anthropophaga*, are deposited in sandy soil contaminated with excreta of animals; the newly hatched larvae attach themselves to animals walking or resting on the soil, and they then burrow beneath the skin where they complete their growth. It has been shown that infected animals acquire an immunity to reinfestation by *C. anthropophaga*; in immune animals, the larvae are killed by a precipitate which forms around the larvae and in the gut. The antigenic substance appears to exist within the excreta of the larva. Species of *Wohlfahrtia* deposit small larvae on the skin of the host; they quickly penetrate and produce lesions beneath the skin in which they grow. Man is frequently attacked and serious damage may result from invasion of the eye, ear, or nasopharynx. It is said that in the range of the Palearctic species, *W. magnifica*, it is dangerous to sleep out of doors in the summer months during the middle part of the day when the adults are active.

Of the cavity and wound myiasis-producing species, *Cochliomyia americana*, the primary screw worm fly of the New World, is of great importance. Females are attracted to abrasions in the skin, caused by scratches, tick bites, and the like, and lay their eggs in packets at these sites. The larvae burrow through the abrasion into the living flesh. Untended infestations are fatal, and large losses of stock are suffered by farmers and ranchers. The permanent range of this species includes the tropics and subtropics but during the summer, through migration and importation of infested animals, it invades the northern states, where serious outbreaks occur from time to time. Occasionally, man is attacked, and extensive damage or even death may result from the invasion of the nasopharynx or other cavities. In the Orient and Ethiopian tropics, *Chrysomya bezziana* has similar habits and is a common cause of myiasis of man, being found in ulcers, the ear, mouth, orbit, vagina, and the like. *Oestrus ovis* females deposit small larvae in the nostrils of sheep; the larvae migrate to the frontal sinuses where they complete their development. The fly also attacks man at times, and may place the larvae in the eye.

Intestinal myiasis is caused in horses by species of *Gasterophilus*, the horse bot. Eggs are glued to the hair of the animal, the larvae find their way to the mouth, and eventually reach the stomach and duodenum where they attach to the mucosa. When mature, they pass out with the feces, and pupation occurs in the ground. In all the species discussed above, mature larvae leave the site of their development on the body and drop to the ground, where pupation occurs. After a few days or weeks, depending upon the weather and the species, the adults emerge. Adults of the oestroid flies (ox warbles, horse bots, etc.) do not feed; their mouth parts are vestigial. However, although they neither bite nor sting, horses and cattle show an instinctive dread of these insects, and may make violent efforts to avoid contact with them.

According to a number of reports in the literature, larvae of blowflies, flesh flies, eflies and anthomyids will cause temporary myiasis in the intestine or bladder. Larvae apparently gain entrance to the intestine through ingestion of foods containing larvae or eggs, or by way of the anus, and to the bladder by way of the uretra. Stool samples frequently contain fly larvae but most of them undoubtedly result from deposition of eggs after the stool has been passed. Rat-tail maggots, of the genus *Eristalis*, breed in water heavily charged with organic matter; they sometimes are ingested accidentally and cause gastric upsets. Other temporary invaders of the alimentary canal are larvae of the soldier fly, *Hermetia illucens*, and of the house shipper, *Piophilha casei*.

A few larvae are external parasites. In Africa, the Congo floor maggot, *Auchmyia luteola*, lives in the dirt of floors of native dwellings and comes out at night to seek blood of available hosts.

For treatment of animals infected with the primary screw worm fly, the U. S. Department of Agriculture recommends "Smear 62," the ingredients of which are as follows: diphenylamine, 3.5 parts; benzol, 3.5 parts; turkey red oil, 1 part; and carbon black, 2 parts. Spray and dips containing DDT and benzene hexachloride promise of being highly effective in controlling sheep wool myiasis.

A recent summary of the Diptera which produce myiasis in man is that of James (1970).

**Order Siphonaptera. The fleas.** The fleas are small, wingless ectoparasites of birds and mammals. They are compressed laterally, and the body is clothed with backward-pointing bristles and spines. The powerful hind legs permit the flea to jump for six inches or more into the air; presumably, this aids the insect in reaching its host. Both males and females are bloodsuckers, and the fleas are responsible for the transmission of plague and murine typhus. Some species remain on the host almost constantly, while others do so only for purposes of obtaining blood, and return to the environment between blood meals. The host-parasite relation is not strict, although most fleas have a favored host species or a few species. The indifference exhibited by fleas to the species of host which furnishes them with blood is of great importance to the epidemiology of the flea-borne diseases, for it makes it possible for the insects to convey infections from their rodent hosts to man, and the vector role is determined not only by the ability to transmit the disease organisms as it is by the association between the fleas, hosts, and man. Rat fleas readily leave sick and dead rats to feed upon man.

Eggs are laid by the female while she is on the host, in which case they even fall to the ground, or while she is in the nest or habitation of the animal. Eggs are produced singly or in small clusters of a dozen or two; and the female flea, under favorable conditions may live for several weeks to a year or more, lay a total of several hundred eggs. The eggs hatch in two days to two weeks. The worm-like larva feeds upon particles of organic matter which it finds in the debris of the host's habitat, such as dried feces, nest material, bodies of dead insects, and blood seems to be essential for proper growth, and the main source of this food appears to be the fecal pellets of dried blood passed by the adult fleas. Blood alone is not a suitable diet for the larvae; micro-organisms are probably necessary to furnish vitamins of the B group. The larvae require periods of from about two weeks to as much as four or five months to complete their development. Mature larvae



spin a cocoon; within the cocoon the larva pupates. Before pupating, the larva may go through a prolonged period of resting within the cocoon; the pupa itself may stay for only a week or for a much longer time, and the adult flea may remain quiescent within the cocoon for long periods when no hosts make their appearance. The total length of time spent in the cocoon has been observed to vary from seven days to over a year. There is, therefore, a great deal of variation in the rapidity of the life cycle; it may be completed in two or three weeks, or it may require considerably more than a year. It would appear that this is of survival value to the flea; as the larvae are free living and pupation occurs in the habitat, the great staggering in the appearance of the adults is insurance that at least some of them will contact the host. From Sharif's studies it would seem that the larva, too, is dependent upon the presence of the host, as it requires the blood passed by the adult fleas which in turn obtain their food from the host. Without it, the larvae go through a period of suspended development, which again is a mechanism for preservation.

Climatic factors have a profound effect upon rapidity of development; high temperatures may hasten the life cycle and high humidity will increase the longevity of the adult, but rainfall is detrimental to the larvae as they prefer a relatively dry breeding medium. It has been suggested that the reason for the high flea infestation of burrowing mammals and birds is that the burrows furnish an environment protected from severe climatic conditions.

Some of the important species of fleas are as follows:

*Pulex irritans*. The human flea. This flea has a cosmopolitan distribution and man is the favored host, although it will attack a wide variety of wild and domestic animals. Pigs are especially attractive, and exceedingly heavy infestations of pig sties may be built up. Such infestations may also develop in and around houses, lumbering camps, and other dwellings; breeding then takes place in the litter under and about the buildings. Adults may even be abundant in the lawn around the house.



Fig. 7-10. The human flea (*Pulex irritans* Linn).

*Xenopsylla cheopis*. The Oriental rat flea or tropical rat flea. Through commerce this flea has attained a tropicopolitan distribution, and it is also widespread in temperate zones. In the United States it was first reported from seaports, but more recently it has been shown to be present in many cities from the north central states. Although a tropical species, it is capable of surviving the winter in these northern

des; presumably the climatic conditions within the protected rodent's burrows in suitable during the cold months. It is the most important of the rat fleas, as the species primarily associated with flea-borne diseases. The adults remain on host for most of the time, and when the rat dies the fleas readily attack another

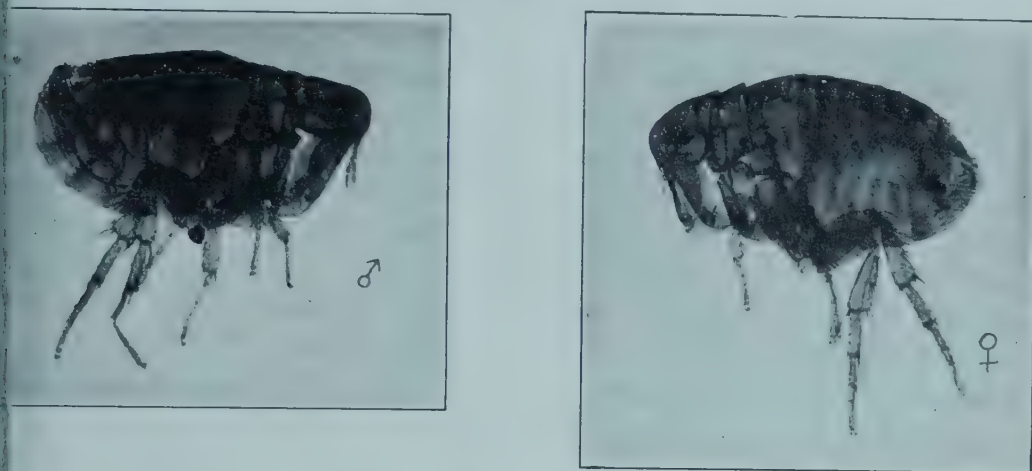


Fig. 7-11. The Indian rat flea (*Xenopsylla cheopis* Rothsc).

which, because of the close association between man and rat, is apt to be man. There are several other species of *Xenopsylla*, of which the tropical *X. astia* and *X. asiatica* are also associated with domestic rats.

*Xenopsylla fasciatus*. The rat flea of the north temperate climates. The effect of climate upon this species and *X. cheopis* is brought out by the study of Davis and others in Baltimore, where *X. cheopis* is the predominant flea on rats during the warm months while *N. fasciatus* is rare; during the winter months *X. cheopis* is rare, and *N. fasciatus* becomes common.

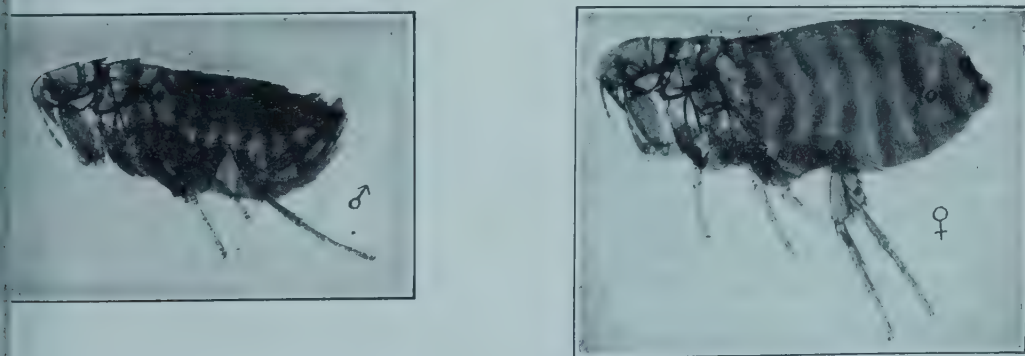


Fig. 12-13. The common rat flea of Europe and North America (*Ceratophyllus fasciatus* Bosc).

*Ctenocephalides canis* and *C. felis*. The dog and cat fleas. Although primarily associated with the dog and cat, respectively, both species will attack man readily as well as other animals. They are common pests in houses.

*Leptopsylla segnis*. The European mouse flea. This species now has almost a cosmopolitan distribution; it is found on domestic rats and mice.

*Spilopsylla gallinacea*. The stick-tight flea of poultry. Rats, dogs, and other animals as well as man, are also attacked. The adults remain attached to the host for long periods of the mouth parts.



*Tunga penetrans*. The chigoe flea. This species is widespread in tropical America and Africa. It has been reported from New Orleans and southern California. The females burrow into the skin and here swell up to about the size of a pea. The males are ejected through the opening in the skin. In favored areas of sandy soil, the flea may be very abundant, and cause great annoyance to barefooted natives especially. Secondary bacterial infections may set in with serious consequences which may require amputation. Obermayer (1943) discusses the treatment of the infestation and if suppuration has not yet taken place, he recommends thorough cleansing of the affected part with soap and water and extraction of the flea with a blunt, heated needle. If the whole flea is not removed, bacterial infection will result. If suppuration has already set in, following removal of the flea the site of infestation should be cleansed with phenol and alcohol, and dressed with a 5 per cent sulfathiazole-sulfadiazine cream. Contact of the bare skin with infected soil should be avoided and the best prophylactic measure is the wearing of shoes.

A number of species of fleas are associated with wild rodents, and are of importance in that they maintain sylvatic plague among these hosts (see page 403).



Fig. 7-13. A squirrel flea (*Hoplopsyllus anomalus* Baker).

**Control of Fleas.** The adult fleas infecting dogs and cats may be killed by dusting the animal with derris powder containing at least 0.5 per cent rotenone or 5 or 10 per cent DDT dust.

Almost all the fleas on wild rats may be killed by dusting the burrows and runways with 5 or 10 per cent DDT. This is a means of typhus and plague control. Macchiavello describes how an outbreak of plague at Tumbes, Peru, was stopped four days after the first application of DDT dust. There was a reduction of over 90 per cent in the flea infestation on rats. A cyanogas foot pump may be used to blow the dust into the burrows and other enclosed spaces suspected of being nesting or harboring places for rats. Dust may also be placed at the entrance of the burrow in order to insure maximum contact of the rat with the DDT. A hand shaker may be used to treat open rat runways. Rats running through treated burrows or runways will pick up sufficient DDT to kill their fleas.

Active adult fleas, as well as the larvae breeding in and about dwellings and animal shelters, may be controlled by spraying with a 5 per cent solution or emulsion of DDT or dusting with a 10 per cent DDT dust. In houses the dust should be applied beneath as well as on rugs. All floors and the basement should be treated.

at the same time the dust should be used on household pets. The various residual sprays used in buildings should prove to be highly effective in eradicating flea infestations. Dimethyl phthalate, Rutgers 612, and indalone will give protection against fleas for two hours or more.

**Order Hemiptera.** The order Hemiptera comprises the true bugs. It is a very large order, and contains many insects which are agricultural pests. The bugs have piercing-sucking mouth parts, and some families have become predaceous on other insects. The bloodsucking species are found in the subfamily *Triatominae* of the family *Reduviidae*, and in the family *Cimicidae*.

Some important species of the *Triatominae* ("cone nose bugs" or "kissing bugs") are *Panstrongylus megistus* in Brazil, *Triatoma dimidiata* in Central and South America, *T. infestans* in western South America, *Panstrongylus geniculatus* in Guyana and South America, *Triatoma protracta* in western United States, and *Triatoma prolixus* in South America. The *Triatominae* have primarily an American distribution, but one species, *T. rubrofasciata*, is tropicopolitan. A few other species are also found in the Old World tropics.

The species of *Triatominae* are associated with certain animal hosts, such as rats, armadillos, bats, and other wild and domestic animals. Some of the species will attack almost any animal. In Central and South America, a number of the species, especially *M. megistus*, *T. infestans*, and *R. prolixus* live in the thatch roofs and walls of man's habitations. In the crevices of the walls and roofs the insects find suitable hiding places, where they remain during the daytime. At night they emerge from their retreats to feed upon the inhabitants of the house, and appear to show no preference for man, dog, or other domestic animals about the premises. The domestic animal reservoirs of *trypanosomes*, therefore, become of considerable epidemiological importance.

The life cycle of the *Triatominae* ordinarily requires about a year for its completion. The adult bugs, which possess wings and are capable of flying into houses, live for several months, during which time a number of blood meals are taken. Females deposit several batches of eggs, which may total several hundred. The eggs are deposited in the hiding places, and usually are glued to the substratum. Depending upon temperature, they require three or four weeks to hatch. There are immature or nymphal stages, and the total period of nymphal development lasts over several months. Each nymphal stage requires at least one full meal of blood before it can moult. The fifth nymphal stage moults into the adult.

The importance of the *Triatominae* as pests and as vectors of *Chagas' disease* is directly related to their association with man, and particularly with their habit of invading the rude dwellings in rural Mexico, Central and South America. Permanent control would involve the destruction of infested huts, preferably by burning, and substitution of these by well constructed, tight dwellings in which the bugs would have no harborages. As it is obvious that such a program is dependent upon social and economic progress, reliance at present must be placed upon the use of insecticides. The new residual sprays have shown much promise. In Chile, Neghme and his co-workers report 90 per cent control of the bugs for three months in several villages following the application of DDT. However, DDT is not the ideal insecticide, as complete eradication was not possible except in a few houses with very low initial infestations. Dieldrin hexachloride appears to be superior to DDT, but it must be used in high



concentrations of 1 or 2 gm. per square meter of surface. It remains effective for three months or more. It should be applied especially to cracks and crevices in walls, the thatch roof, beds, and all other possible hiding places. The possibility of development of strains of bugs resistant to the halogenated compounds through widespread use of the residual insecticides must be kept in mind. Pyrethrum may be used as a space spray; it will drive the insects out of their hiding places, but has no residual effect.

The *Cimicidae*, or *bedbugs*, are completely wingless. There are two species which attack man: *Cimex lectularius*, the temperate bedbug, and *C. hemipterus*, the tropical bedbug. Between them they infest all parts of the world inhabited by man. These bugs live in cracks and crevices in man's habitations, particularly in sleeping chambers, and they also infest animal shelters. During the day they remain hidden within their shelters, but at night they emerge to feed upon man or any warm-blooded host that may be available.

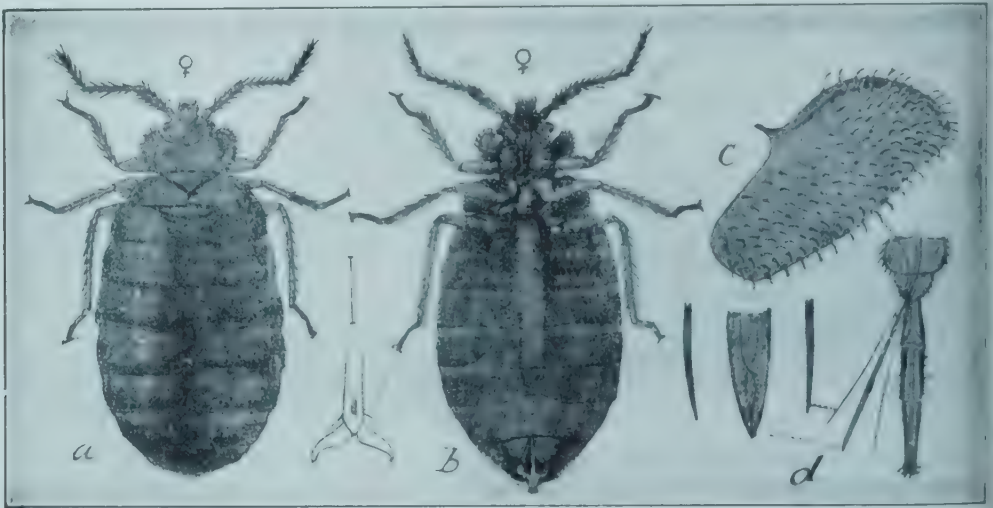


Fig. 7-14. The bedbug.

a, adult female, gorged with blood; b, same from below; c, rudimentary wing pad; d, mouthparts. (After Marlatt.)

blooded host that may be available. The adult bugs are capable of living for months, even when starved. They take blood at frequent intervals, and the female deposits a number of small batches of eggs. Several hundred eggs may be deposited eventually by the female in the hiding places, where they are glued to the substrate. The eggs hatch in a week or two, depending upon temperature, and there are five nymphal stages, each one of which requires a full meal of blood. Three or four days may be spent in each of the nymphal stages under suitable conditions of temperature and availability of hosts, but at low temperatures or when hosts are not available the nymphs may live for weeks or months. Under optimum conditions the bugs complete their life cycle in about a month, and there may be several generations a year.

Control of bedbugs has been a difficult problem in past years because of the difficulty in getting at the insects in their hiding places. Superheating and hydrogen sulfide fumigation were perhaps the best measures. The residual insecticides are now known to be especially effective against bedbugs. The insects must crawl out of their hiding places in order to reach their hosts at night, and a barrier of a residual insecticide

exterminate them in the treated premises. A 5 per cent residual spray of DDT is perhaps the most effective, but a 10 per cent DDT dust may be used where it is possible to spray. The spray should be applied to mattresses, bed springs and heads, and to the walls, particularly around the baseboards. Inspection will find the most likely hiding places of the bugs, and the spray or dust must be applied especially at them.

**Order Anoplura. The lice.** There are two kinds of lice, the *Mallophaga* or bird lice which do not suck blood, and the bloodsucking *Anoplura*. The latter infest a variety of animals, and three forms are found on man: the body louse, *Pediculus humanus* (often called *corporis* or *vestimenti*) the head louse, *P. capitis*; and the crab louse, *Phthirus pubis*. The body lice and head lice are different populations or subspecies of a single species.

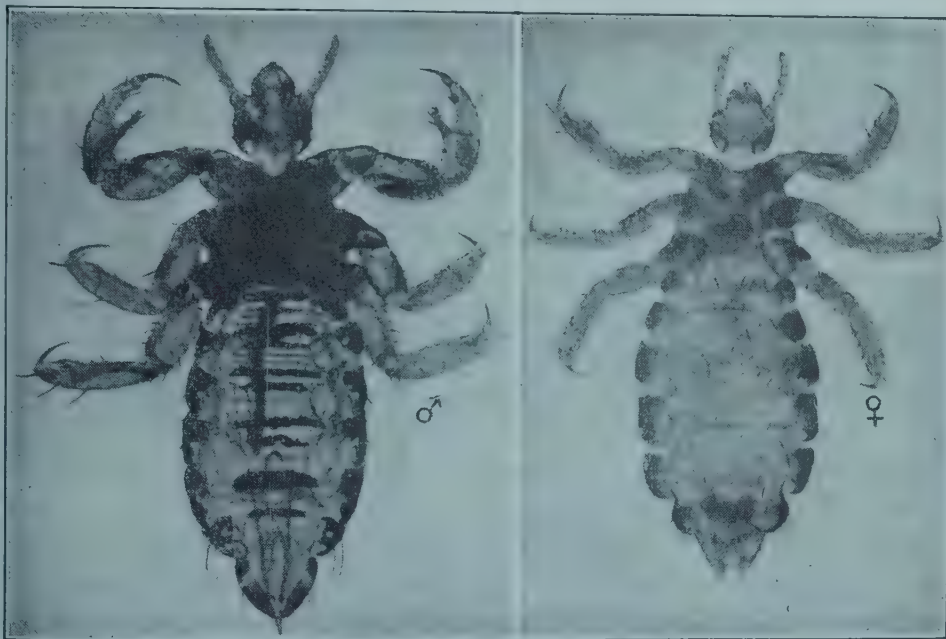


Fig. 7-15. *Pediculus humanus* var. *Corporis*.

The life cycles of these lice are essentially the same. The eggs of the body louse are found in the clothing, and are glued to the cloth especially along seams and in folds. The gregarious females tend to lay their eggs where other eggs have been deposited. A female will lay from one to a dozen eggs a day, and under normal conditions a female may produce a total of 275 to 300 during the course of her life of a month or two. When kept continuously on the body, the following developmental periods for the various stages in the life cycle have been observed: egg, eight days; first nymph, two days; second nymph, two days; and the pre-reproductive period, one day. The total cycle, therefore, requires 16 days. Pairing occurs within a few hours after the adult stage is reached. The rapidity of this cycle depends upon temperature, and each of these stages may be considerably delayed in lice in clothing that is removed from the body. Under these conditions, hatching of eggs may be delayed for as much as 24 days, while the active stages may survive for a week or 10 days even when they are unable to obtain food.



All the active stages of lice require blood; they take small meals at frequent intervals. In the process of feeding, small denticles at the mouth opening anchor the louse to the skin; needle-like stabbers then pierce the tissues and cause a flow of blood. The sucking lice are extremely host specific; a given host has only its own species of lice. Recently, however, strains of human lice have been adapted in the U. S. Department of Agriculture laboratories to exist upon rabbits.

*Body lice* are most numerous in the layers of clothing next to the body. Once an infestation has set in, the chief factor influencing density is the changing of undergarments. McCleod and Benson state that infested persons "very soon become victims of their own habits." The louse population may build up very rapidly unchecked, and occasionally an individual may possess thousands of the insects in his clothing. Scratching and restlessness on the part of heavily infested persons may cause the lice to wander about and reach the outer surface of the clothing, from which they may be readily transferred to other persons. Thus, in crowded tenement houses, prisons, refugee camps, and the like, lice may spread rapidly through the entire population. Under unsettled conditions or times of war or disaster, when prisoners, refugees, or troops are unable to change clothing or bathe regularly, the body louse infestation may increase to the point where epidemic typhus, trench fever, and relapsing fever break out. This is particularly true during the winter, when bathing is made more difficult by the cold weather.

Lice are sensitive to temperature, and move away from a person with a high fever, or from a cold cadaver. Thus, persons working with the sick and dead are most apt to encounter infected lice. Lice are also disseminated by means of clothing, bedding, and other articles used by infested individuals. In times of peace, the majority of louse infestations will be found among the poorer classes of people among whom lack of facilities reduces the frequency of bathing, and the changing and laundering of clothing.

The *head lice* live in the hair of the head. The eggs are glued to the roots of the hair. The total developmental period requires about 17 days. Buxton (1941), who made a study of head louse populations in crops of human hair, noted that the numbers of lice were greater in heavier crops of hair, that women were more heavily infested than men, and boys more heavily infested than adult males. Occasionally there may be over a thousand lice on the head, but the usual infestation is much smaller than this, numbering 10 or less individuals. The limitation in size is due not only to grooming and conscious delousing efforts on the part of the host, but also to some natural checks. In small populations, one sex predominates. Progeny of a single female are often almost all of one sex, and an infestation started by a single immigrant female would thus be unisexual and unless supplemented by additional immigrants of the opposite sex, the infestation would be short lived. If the infestation becomes established successfully, so that the lice increase to 100 or more individuals, males outnumber the females. By their frequent and violent copulations the males greatly shorten the life of the females, which causes the oviposition rate to drop.

The *crab lice* ordinarily live in the hair of the pubic region, but they may also be found in the arm pits and even in the eyebrows and eye lashes. They may be generally distributed over the body of a hairy person. This species is thought to

inated mostly by coitus, but infestations may also be acquired by other means. Children with eye-lash infestations unquestionably are infested by lice wandering from infested parents. Pubic hairs to which nits are attached are often removed from the body, and larvae hatching from these eggs may be picked up from clothing, toilet seats, wrestling mats, and the like. Nuttall observed a life cycle that required 22 to 27 days for completion.

In addition to being vectors of *epidemic typhus*, *relapsing fever*, and *trench fever*, lice are directly responsible for irritations and for a skin condition known as "vagabond" disease, which is characterized by rough, thickened, and deeply pigmented skin. Severe skin reactions are considered by Peck and others (1943) to be due to development of hypersensitivity to the louse feces. These authors observed that persons without previous contact with lice, the bites caused only minute, noninflammatory and nonpurpuritic points which were flat with the skin. The hemorrhage was minute. Hypersensitivity developed after 7 to 10 days of daily exposure, and inflammatory reactions set in. At the site of the bite, rupture of the capillaries caused a purpura; the skin became red, edematous, and studded with vesicles. This condition subsided in five to eight days, leaving a brownish pigmentation. A general feeling of illness may be produced by large numbers of the insects, with dull headache, low fever and pains in the joints.



From Soper, Davis, Markham, and Riehl, *Am. J. Hyg.*, 45:305, Fig. 16, 1947.

Fig. 7-16. Seventh step in dusting an individual.



The *control of lice* was vastly improved during World War II. Instead of employment of elaborate delousing stations, which utilized steam, dry heat, or fumigants for destruction of lice in clothing, louse powders were developed which could be applied to the clothing and body and eradicate an existing infestation as well as protect against reinfestation without the necessity of bathing and sterilization of clothing. Some success was obtained with powders containing derris and naphthalene (the AL 63 powder) and pyrethrum plus a synergist and antioxidant (MYL powder), but these were replaced by DDT when the latter became available. A 10 per cent DDT powder in pyrophyllite may be applied liberally by the individual user from a sifter-can container to the underwear and the inner surface of the outer garments. The powder should be distributed by hand, with particular attention being paid to the seams. For treatment of large groups of people, the powder is blown by means of a hand duster between the skin and clothing and between the layers of clothing. About one and one-half ounces of powder is required per person. Mass treatment with louse powders is credited with stopping epidemic typhus in Naples in 1944 and in the Belsen concentration camp in 1945.

Where lice have become resistant to DDT, the 1 per cent lindane powder may be substituted for DDT.

The *head louse* also may be controlled by applying the 10 per cent DDT powder to the hair of the head. A second application after a week or 10 days may be necessary to kill lice hatching from eggs subsequent to the first treatment. Successful control of head lice has been reported with the following formula:

Phenyl cellosolve . . . . .	5 parts
Ethanol . . . . .	47.5 parts
Water . . . . .	47.5 parts
Perfume to give a slight pleasant odor.	

The patient while being treated holds a towel to his forehead so that none of the lotion can run into the eyes. The hair is wetted thoroughly with the lotion, rubbed into the scalp, and the excess wiped off. This material kills eggs as well as the active stages. Busvine and Reid report highly successful head louse control through the use of 0.2 per cent benzene hexachloride in coconut oil.

The DDT powder is *effective against the crab louse*; it should be rubbed into the hairy parts of the body, so that it reaches the base of the hairs. The NBIN formula was developed as a combination treatment for lice and scabies.

NBIN formula:

Benzyl benzoate (scabicide) . . . . .	68 parts
Tween 80 (emulsifier) . . . . .	14 parts
Benzocaine (ovicide) . . . . .	12 parts
DDT (lousicide) . . . . .	6 parts

The DDT and benzocaine are dissolved in the benzyl benzoate; the Tween 80 is then added to make an emulsion concentrate. For use on the body, one part of the concentrate is added to five parts of water. For control of head lice, about 20 ml. of the emulsion may be applied to the head, care being taken to protect the eyes. A single treatment will eradicate lice from the body; eggs as well as the active stages are killed. The emulsion may be applied by means of a sponge or it may be sprayed upon the body. All parts of the body should be treated, and about 50

person are required. Following treatment, bathing should be delayed for 24 to 48 hours.

**Class Arachnida. Superfamily Ixodoidea (the ticks).** There are two families of ticks, the *Argasidae*, or soft ticks, and the *Ixodidae*, or hard ticks. The soft ticks are vectors for *endemic relapsing fever*, and the hard ticks are vectors of *rickettsias*, *typhus*, and several diseases of animals.

The ticks are rather degenerate parasites. The body, which in unfed ticks is compressed dorsoventrally, shows no segmentation; the head or capitulum is retracted and bears an elongate hypostome which anchors the tick to the flesh of the host and two rod-like chelicerae which are used for penetrating the host's tissues, and two pairs of hollowed palpi which are presumably sensory and also form a sheath for the mouth parts. There are four pairs of legs in the nymphal and adult stages, but the larvae have only three pairs. Eyes, when present, are simple ocelli situated on the sides of the body at about the level of the second pair of legs. Hard plates on the dorsal and ventral surfaces of the body give the name of "hard ticks" to the *Ixodidae*. The leathery posterior portion of the body of the female hard tick is distensible of great distension to accommodate the large meal of blood. With a few exceptions, all stages of the ticks require blood.

The life cycle of the soft ticks may be illustrated by those of *Ornithodoros* *taeniophorus*. It lives in native huts, where it feeds upon man and domestic animals. The eggs are deposited in hollows burrowed by the female in the sand or soil of the floor of the hut. The incubation period requires 8 to 25 days. The larva is unable to feed while still in the egg shell it moults in 3 to 13 days to the first nymphal stage. The nymph is active, and comes out at night to feed upon an available host. If the nymph is destined to become a male adult, it moults three to five times; if it is a female it moults three to seven times. A single blood meal is taken between each moult and each stage requires 5 to 13 days. Should the nymph be unable to find a host it can survive starvation for more than a year. The adult males and females feed intermittently, but can resist starvation for 10 months or more. Fertilization takes place in the crevices about the floors and walls of the hut which serve as hiding places for the active stages. Following fertilization and feeding the female may start laying eggs after eight days. Eggs are laid in small batches at intervals of several days between the intermittent feedings. Adults may live for a year or more.

***Argas persicus*. The fowl tick.** In the southern United States it is known as the *chick tick*. It is found throughout the warmer parts of the world. Domestic fowls are its favorite hosts. The active stages hide in crevices in the hen house, and come out at night to feed. The larvae remain attached to the host for 3 to 10 days; then detach and seek a suitable shelter, where they moult to the first nymphal stage. There are three nymphal stages. The nymphs and adults feed rapidly, taking only small meals of blood. Adults may live for three years or more, and all stages can withstand starvation for months.

The hard ticks differ from the soft ticks not only in morphology but also in their life cycle. This cycle may be illustrated by that of the Rocky Mountain *tick*, *Dermacentor andersoni*. This species is found in the Rocky Mountain region of the United States and Canada. The natural habitat is the fields and woods in which the host animals live, and as the mountain range is subjected to severe winters the ticks hibernate as unengorged adults or nymphs in suitable shelters under



bushes, etc., on the ground. During the first warm days of spring the adults emerge from their hiding places and crawl onto bushes or other vegetation where they wait for a host to pass by. Hosts of the adults are larger mammals such as cattle, sheep, and man. When they brush through the vegetation in which the ticks are resting the latter attach themselves quickly. On the host, the adult male takes a number of small meals of blood; between feedings it seeks out the females which are attached by their mouth parts to the host. The male crawls beneath the attached female and effects coitus. A male will mate with several females. The males remain active for a long period of time, and it has been suggested that because they feed often, the males may be especially important in transmission of animal diseases such as anaplasmosis. The female and immature stages of hard ticks take only one meal of blood, so that disease organisms must survive from stage to stage and generation to generation in order to reach a new host; the males, on the other hand, may leave a dead animal, or be transferred from animal to animal upon bodily contact of the hosts, and thus become potentially a more effective mechanism for immediate transfer of pathogens.

The female, although attached to the host, does not begin to engorge until after she has been fertilized. Engorgement is completed in 9 to 10 days, and the greatly distended tick then drops to the ground, where she finds a crevice or some other suitable hiding place, and after a preoviposition period of a week to a month, eggs are laid over a period of about three weeks, in a single large batch numbering several thousand. The adults are active until midsummer. The eggs undergo an incubation period of about a month, so that the six-legged larvae appear in the early summer and are active until late summer. They attach themselves to various species of rodents and not to large mammals. They engorge in two to eight days; then drop off and find a hiding place on the ground. After a quiescent period of about three weeks the eight-legged nymph appears. By this time the season is well advanced. In the fall the nymphs emerge and attach themselves to small mammals such as ground squirrels and rabbits, but not to large animals. The nymphs engorge in 4 to 9 days, but if unable to find a host they may live for 10 months or more. The nymphs may be found, therefore, throughout the summer and it is possible for them to overwinter a second time. The engorged nymph goes through a quiescent period on the ground of three or four weeks, and then moults to the adult stage. These adults, emerging late in the summer, do not feed before going into hibernation. The total life cycle, therefore, requires two years for its completion. Adults which do not encounter a host will live for months, and so they, too, are able to overwinter at least twice. Some ticks, therefore, may require at least three years to complete their development.

Each stage of *D. andersoni* thus requires a separate host. Periods of attachment alternate with quiescent and host-seeking periods spent in the habitat. This is known as a three-host cycle. An important point in the relation of this cycle to the epidemiology of diseases is that the immature stages feed upon rodents and the adult stages attack large animals and man. Thus, rodent microparasites taken up by larvae and nymphs can be transmitted to man by the adults.

*Dermacentor variabilis* is the American dog tick. Its range includes most of North America except for the area inhabited by *D. andersoni*. Dogs are the preferred host of the adult ticks, but other large animals, as well as man, are also

y. The immature stages are found on wild mice and other rodents. The developmental cycle is much like that of *D. andersoni*, but there are variations in the life cycle depending upon latitude. In colder regions adults overwinter and are



Fig. 7-17. A Rocky Mountain spotted fever tick (*Dermacentor andersoni*). 1, adult female, unengorged, dorsal view; 2, adult male, dorsal view; 3, adult female, unengorged, ventral view; 4, adult male, ventral view; 5, adult female in act of depositing eggs.

in early summer, but larvae and nymphs may be found on their rodent hosts throughout the winter. The ticks may be encountered in wooded and grassy areas. Because of the preference for the dog as a host, they are more closely associated with the human environment than is the Rocky Mountain wood tick. *Haemaphysalis sanguineus*, the brown dog tick, is a common pest in houses and kennels. All stages attack dogs. In the Mediterranean region this species attacks



man as well as dogs, but in the Americas man seldom appears to be bitten. It has wide distribution in the tropics and subtropics, and its range seems to be expanding rapidly perhaps through movement of dogs. In the United States it was known a few years ago only from Brownsville, Texas, but now it is fairly generally distributed throughout the country.

*R. appendiculatus*, *R. sinus*, and *R. evertsi* are important pests of domestic animals in Africa.

*Haemaphysalis leporis-palustris* does not attack man, but appears to be of importance in that it may help maintain a reservoir of infection of diseases among rabbits. All stages attack rabbits, and the immature stages are found as well upon ground inhabiting birds. It is found throughout North America and has been reported from Mexico, Central and South America.

*Boophilus annulatus*, *decoloratus*, etc., attack cattle and as the larvae, nymphs and adults remain on the host continuously, these species are known as one-host ticks. They are vectors of piroplasmiasis. Through systematic dipping and quarantine *B. annulatus* has been exterminated from the United States, except possibly in a few small inaccessible pockets along the Gulf Coast.



Fig. 7-18. The Texas fever tick (*Boophilus annulatus*).

*Amblyomma americanum* attacks man and wild and domestic animals in North America and Mexico. It is said to be present in South America also.

*A. cajennense* is found in Mexico, Central and South America, and the West Indies; it is also reported from the tip of Florida and the vicinity of Brownsville, Texas. Wild and domestic animals serve as hosts, and all stages will attack man.

*A. maculatum* is of considerable economic importance in the southern United States. The adults attach to the ears of cattle and other animals, and the wounds made by them induce oviposition by the destructive primary screwworm fly. Immature stages of this tick feed upon small wild animals and birds.

*A. hebraeum* and *variegatum* are important parasites of domestic animals in Africa.

The genus *Ixodes* contains a number of species which are found upon wild and domestic animals. Some of them attack man as well. Important species are *I. holocyclus* in Australia, *I. ricinus* in Europe, *I. persulcatus* in Russia and Siberia, *I. scapularis* of southeastern United States and *I. pacificus* of the west coast of United States.

Aside from their role as disease vectors, ticks are important parasites because

the direct effects of their bites, which result in irritation and blood loss. Jellison and Kohls (1938) describe a tick-host anemia due perhaps to exsanguination of the host by large numbers of the parasites, although the authors suggest the possibility of the introduction by the tick of a substance affecting the hematopoietic system or which destroys the blood cells. Normal bites produce an edematous inflammatory lesion, but Trager (1939) has shown that an immunity can be acquired to ticks. Guinea pigs previously infested by larval *D. variabilis* respond to reinfestation with a leukocytic infiltration of the tissues in which the mouth parts of the ticks were inserted. The epithelium at the edges of the bite area becomes thickened and folds down beneath the mass of leukocytes. The tick thus becomes walled off from the source of blood and dies without becoming engorged.

Tick paralysis is caused by females of certain species of ticks. Males are seldom involved, presumably because they take only small meals of blood. The paralysis is presumed to be due to a toxin contained in the salivary secretion of the slowly engorging female. The offending tick is usually found attached to the head or in the vicinity of the spinal column; however, paralysis may also be caused by ticks attached to other parts of the body. It begins at the lower extremities and gradually ascends; if the tick is not discovered and removed death may ensue. Tick paralysis causes considerable loss among domestic animals. Man is also affected, and a number of cases have been reported in children. Cases in children are likely to be confused with poliomyelitis. Removal of the tick results in recovery. Ticks known to be capable of causing paralysis include *D. andersoni* and *variabilis* in North America, *Ixodes ricinus*, *Haemaphysalis cinnabarina*, and *Boophilus calcaratus* in Europe and the Mediterranean region; *I. pilosus*, *I. rubicaudus*, and *Rhipicephalus* in Africa, and *I. holocyclus* in Australia. Ransmeier (1949) has recently described several cases which he observed in children.

The control of ticks may be considered under the headings of protective measures and measures of attack. Persons entering tick-infested areas may protect themselves by wearing clothing through which ticks are unable to penetrate. This may include the use of boots into which the trousers are tucked. Following exposure the entire body should be examined for the presence of ticks. Although the mouth parts may be inserted into the flesh, actual engorgement proceeds slowly, and prompt inspection will prevent feeding or at least possible introduction of pathogens. Engorged ticks may be removed by a steady pull with the fingers or forceps. Care should be taken not to break off the mouth parts, and as infectious agents exist in the tissues, crushing of the tick must be avoided. The point of attachment may be treated with a solution of carbolic acid, silver nitrate, or iodine.

Various compounds have been tested as repellents, but none so far has been found to be completely satisfactory. Indalone, dimethyl phthalate, and benzyl acetate were found to give some measure of protection against immature stages. These materials were tested at the rate of 150 to 200 ml. per suit of clothing. They may be used as barriers by impregnation of a four- to six-inch wide strip of material along the margins and openings of the clothing, such as the sleeve openings and cuffs of trousers. Brennan (1948) reported excellent protection for 10 days against nymphs and adults of *A. americanum* through impregnation of clothing with an acetone solution of N-butylacetanilide. Each suit received two ounces of the solution. Garments may also be impregnated by dipping in a 5 per cent emulsion.



Cole and Smith (1949) also found it to be an effective repellent and safe for use on clothing at the rate of 2 gm. per square foot of cloth, but stress the fact that it is very toxic when applied directly to the skin. Since it should not come in contact with the skin, untreated underwear should be worn with impregnated clothing. Other materials are in the process of being tested but cannot be recommended until after their effectiveness and toxicology are better known.

Ticks may be attacked either in the environment or while they are attached to their animal hosts. Dogs may be treated with derris powder containing at least 2 per cent rotenone, or with a 10 per cent DDT dust. The derris appears to be more effective than DDT against the American dog tick. Bishopp and his associates recommend a dip made of two ounces of derris or cube powder, one ounce neutral soap, and one gallon of tepid water. After being applied thoroughly to the dog, it is allowed to dry on.

Large animals are treated with various tickicides in the form of dips, washes, sprays, and smears. Dips containing arsenic, rotenone, nicotine, coal-tar creosote, cresol, and sulphur have been widely used. Detailed instructions in their use is given in Bulletins No. 798 and 1057 of the U. S. Department of Agriculture. As a result of a great deal of experimentation in the use of DDT, benzene hexachloride, and related compounds, the U. S. Department of Agriculture at present recommends toxaphene or a mixture of DDT and lindane for treatment of domestic animals with sprays or washes. Sprays are prepared by diluting with water emulsion concentrates or wettable powders. The toxaphene spray should be diluted to 0.5 per cent and the DDT-lindane spray to contain 0.025 per cent lindane and 0.5 per cent DDT. They may be applied by means of power sprayers or hand sprayers to all parts of the animal and to the ears. These materials will eliminate the initial infestation and give protection against further attack for two or more weeks.

Premises such as poultry houses, dog kennels, dwellings, and caves may be treated with residual DDT or the other chlorinated compounds. The 10 per cent DDT dust may be used effectively in homes and kennels against the brown dog tick.

For area treatment, Gouck and Smith (1947) found that spraying of vegetation with emulsions at the rate of one to two and one-half pounds of DDT per acre gave varying results against *D. variabilis* but they consider that from two to three pounds of DDT per acre would bring about satisfactory control. One pound DDT per acre brought about effective control of *A. americanum* and *I. scapularis*.

**Parasitoidea.** This superfamily contains a large number of mites, some of which attack man and animals. Some of the latter are serious pests and also act as vectors of diseases.

*Liponyssus bacoti*, the tropical rat mite, has a wide distribution and appears to have been carried from the Mediterranean region by rats. The habitat of the mite is rat harborages; those situated in and about houses will permit the mite to transfer their attention from rats to man. The active nymph and the adults are parasitic and require blood for their development and for oviposition. On man, all parts of the body may be attacked, but there is a preference for the areas with the most tender skin. The victim may respond with a dermatitis consisting of pruritic, papular eruption; scratching may result in secondary infection. It has been thought that this mite is responsible for maintenance of murine typhus and

and its transmission to man, but it would appear that it is not a very efficient vector of either murine typhus or rickettsialpox. It is a natural transmitting host of the mite of cotton rats, *Litomosoides carinii*.

The adult female, *L. bacoti*, can become engorged in 10 minutes, but because feeding is interrupted frequently, she may remain on the host for as long as several days. She may wander from one host to another before completing feeding. Males, which take only small meals of blood, may also remain on the host for as long as two days. The female may live for two months or more, during which time she will engorge several times and lay several small batches of eggs. Fertilized females produce eggs parthenogenetically which give rise only to males; males are capable of fertilizing females. Eggs are laid in the nest or burrow of the host; they hatch into six-legged larvae which do not feed; the larva sheds its skin and so becomes the eight-legged protonymph which attaches to the host for a blood meal; it then transforms to the nonfeeding deutonymph, which eventually moults to the adult stage. The entire cycle may take as little as 13 days. Control of this mite is primarily one of rat control. DDT dust appears to have no effect upon it.

Other species of *Liponyssus* are parasites of birds. *Dermanyssus gallinae* is the common chicken mite. Although encephalitis viruses have been isolated from them, these mites are no longer thought to act as vectors or reservoirs for these viruses. *Dermanyssus sanguineus*, which parasitizes rats and mice, will also attack man, and this species has been shown to be a vector of rickettsialpox. *Echinolaelaps* and related species are common on rats; they do not attack man.

**Libyosomaidea.** Some species of these free-living mites are intermediate hosts of *Haemonchus contortus*, the tapeworm of sheep. Infection of the sheep occurs through the action of the mites living in the grass; the mites become infected by eating the faeces passed with the sheep's excreta. Certain other tapeworms of animals go through part of their developmental cycle in these mites.

**Personemidae.** To this superfamily belongs *Pediculoides ventricosus*, the grain mite. The female retains within her body the developing young until they reach maturity, and thus becomes greatly distended. The mites feed upon insects and grains, straw, and other plant materials. When handling such materials, or when sleeping upon straw-filled mattresses, the mites will attack man and cause dermatitis with vesicles and pustules which may be quite severe and cover the whole body. Pruritis is intense, and it may be accompanied by mild fever and albuminuria. The condition is remedied by further avoidance of straw or other sources of infestation.

**Tyroglyphidae (Tyroglyphoidea).** This superfamily contains a number of tiny mites which live in stored foods, grains, etc. People handling these materials are affected by a pruritic eruption known as "grocer's itch," "copra itch," etc. The lesions consist of small erythematous papules which develop on those parts of the body which come into contact with the material. Hase (1929) considers that the dermatitis due to the tyroglyphids and also to *P. ventricosus* is the result of allergy which develops through contact with the mites. The mites do not necessarily cause the dermatitis by their bites; rubbing of dust or infested materials containing the mites on the skin will produce the dermatitis very rapidly in sensitized persons.



There are many reports of tyroglyphid mites being found in the digestive and urinary tracts. In the intestine the mites appear to be able to live for a time, but it would seem rather doubtful that they could reproduce and set up a permanent infestation. Some patients, however, may be affected for months. It is possible that such persons are continually reinfesting themselves by ingestion of contaminated foods. As an example of how heavily infested foods may be, Hase estimated that in a feed box containing bran there were 3,000 *T. longior* per square centimeter of surface. He concludes that the severity of the intestinal symptoms depends upon the degree of sensitivity to the mites on the part of the patient. It has been suggested that the mites may gain entrance to the urogenital tract through use of unclean catheters and douche tips.

Inhalation of mite-laden dust may produce asthma and bronchitis, which is accompanied by a high eosinophilia. Carter and others (1944), who examined patients suffering from tropical eosinophilia, observed *Acaroid* and *Tarsonem* mites in the sputum and suggested that they could be the causative agents of this condition. Treatment with organic arsenicals appears to be effective.

**Demodicoidea.** *Demodex folliculorum* is a minute, elongate mite which lives in the hair follicles of man. It is thought by some that there is a high rate of infestation. Ordinarily the mites appear to cause no symptoms. Several species of *Demodex* infest animals; dogs suffer severely from demotectic mange.

**Sarcoptoidea.** This superfamily contains a number of parasites of birds and mammals, including *Sarcoptes scabiei*, which causes scabies in man. Animals have their own scab mites, and although animal breeders occasionally acquire mites from domestic animals, these infestations appear to be transitory. *Human scabies* are acquired through contact with other infested people, and the disease spreads through groups of people living in intimate contact. The disease is often a problem among military personnel, school children, and the like, but from Mellanby's (1941) observations it would seem that to acquire scabies far more intimate contact is necessary than that ordinarily occurring between soldiers, school children, or workers in industrial plants. In view of the widespread belief in the extreme contagiousness of the disease, it is well to review in some detail Mellanby's experiments. Mellanby found that blankets and underclothing were not a source of infestation a day or two after they had been used by scabies patients. In his experiments, volunteers who used a bed immediately after it had been vacated by a scabies patient failed to acquire the mites. In 32 experiments, volunteers did not acquire the mites from underclothing immediately after it was removed from scabies patients; only 1 of these men developed infestations. The mites were readily transferred from one person to another who slept together, and Mellanby concludes that scabies is normally transmitted by personal contact either of a slight or of a venereal nature. However, many people who have had experience with scabies will insist that intimate contact may indeed be slight for transmission to occur; Bhandari recently suggested that a dry, cracked skin is one condition which permits an infestation to take place readily.

The pregnant female mite burrows into the horny layer of the skin, and when scratched out, remains in her burrow for the rest of her life. Egg laying begins a few hours, and the eggs appear at the rate of two or three a day for about 2 months. Larvae hatch from the eggs in three or four days; they leave the burrow

enter the hair follicles. The larvae moult to the nymph stage; the nymphs also moult in the hair follicles. The nymph moults to become either an adult male or an immature female. The males make short burrows, but it is thought that they spend most of the time on the skin, in search of immature females. Mating probably takes place on the surface of the skin, and the pregnant female then enters her burrow. The entire life cycle requires 10 to 14 days. It is thought that transmission from one host to another is usually accomplished by the newly fertilized female.

Mellanby found that infestations occur most frequently on the hands and other sites are the elbows, feet, penis and scrotum, buttocks, axillae, and in women, the nipples. In very young children all parts of the body are attacked.

Neurotic scabies occurs when the patient becomes sensitized to the presence of the mites. This takes place about a month after the infestation has been acquired. At first there is severe itching sets in which may keep the patient awake at night; this, accompanied by a rash which occurs in patches, is highly suggestive of scabies. The diagnosis should be based upon the finding of the mites in the burrows. Once an infected burrow is found, the mite can be removed from the end of the burrow with the point of a needle. In sensitized patients vesicles form behind the burrows in the deeper layers of the epidermis, but according to Mellanby they also occur independent of the burrows. Follicular papules are thought to be due to the presence of the larvae and nymphs. Scratching permits bacterial invasion of the skin and may lead to pustules, boils, impetigo, or eczema. Norwegian or crusted scabies refers to severe infestation accompanied by thick crusts consisting of dried mites, dead epithelium, and dead mites. Mellanby suggests that this may develop in persons who have become immune and tolerate great numbers of the mites without responding by scratching.

Because the mites are unable to live for more than a short time away from the skin, the sterilization of bedding or other fomites would hardly appear to be necessary. Frequent laundry and cleaning will destroy the mites in the clothing. As the infestation is most likely to spread to all members of the family, treatment should be given to the entire family.

In treating scabies, a distinction must be made between the destruction of the mites in the skin and the curing of the secondary bacterial infections. Following the removal of the crusts through bathing and rubbing of the skin with a cloth, the scabicide may be applied, and then, if bacterial infection has occurred, the latter may be treated with calamine lotion, 2 per cent silver nitrate solution, or with other remedies recommended by dermatologists.

The destruction of the mites in the skin is not difficult, and may be accomplished without the preliminary bath. Sulphur has been a time-honored scabicide, and may be used effectively as an ointment containing 10 per cent sulphur. The ointment may be incorporated in a vanishing cream base. The disadvantages of sulphur ointment are its messiness and the possibility of dermatitis due to over-application.

More recently, benzyl benzoate has been shown to be an effective scabicide. A cream may be formulated of equal parts of soft soap, isopropyl alcohol, and benzyl benzoate (Obermayer, 1943). The following emulsion is easily made and according to Mellanby is practically painless even to babies:



Benzyl benzoate . . . . .	200 ml.
Stearic acid . . . . .	20 gm.
Triethanolamine . . . . .	5 or 6 gm.
Water . . . . .	enough to make 1,000 ml.

Melt the stearic acid with the benzyl benzoate in a water bath. Mix the triethanolamine with half the quantity of warm water and pour into the stearic acid-benzyl benzoate mixture cooled to about 30° C; shake to form an emulsion and add water to produce required volume.

Treatment with this emulsion may be preceded by a bath if facilities are available. After the patient is dried, the emulsion is applied to the entire body from the neck downwards; this may be done with a paint brush. The material is allowed to dry on the body. A single treatment will ordinarily eradicate the infestation but a second treatment on the following day or within a week may be advisable in some cases.

The NBIN concentrate, as noted above, is a combination treatment for scabies and lice. It is diluted with 5 parts of water and about 60 to 75 ml. are sprayed or sponged over the body. The patient should not bathe for 24 hours. A single treatment is usually sufficient, but occasionally a second treatment may be desirable after about a week.

Benzene hexachloride is toxic to *Sarcoptes*, and recently Edeson and Wharton reported that a 0.2 or 0.5 per cent solution of the gamma isomer of benzene hexachloride in cocoanut oil gave results that were as good as those obtained with the benzyl benzoate emulsion. The material was applied to all the body except the head with a paint brush. One should note that these tests were conducted upon experimental cases of scabies, and that neither the benzyl benzoate nor the benzene hexachloride solution was effective if applied only once.

A useful summary of the biology and control of scabies is given in a manual by Mellanby (1943).

**Trombidoidea.** These are the harvest mites; the larvae are called "*chiggers* or *red bugs*." The adults and nymphs are free living, and appear to feed primarily upon the eggs of insects which they find on the ground in the shelter of clumps of grass, vegetative debris, etc., which forms the habitat for the mites. The larvae are parasitic upon arthropods or vertebrates; among the latter are a number of species belonging to several genera which attack man. The latter, in addition to being severe pests, are vectors of *scrub typhus* or *tsutsugamushi disease*. The life cycle of the *Trombiculids* may be summarized as follows: the adult female, which may live for over a year, lays her eggs singly at the rate of 1 to 15 per day on the surface of the ground. They hatch into a quiescent deutonymph, from which the parasitic six-legged larva emerges. The larva attaches itself to an appropriate host and remains there several days, and when engorged, drops to the ground. It finds a suitable shelter and transforms to the quiescent nymphochrysalis stage. After several days an active nymph appears, which lives for two weeks to two months before it becomes quiescent and becomes the imago-chrysalis. The adult emerges in about a week.

In feeding, the larva grasps the skin of the host with the palpal claws, pierces the skin with the chelicerae, and then injects a salivary secretion which dissolves the tissues of the host. The host tissues react by forming a tube, called a "stylostome," and the mite sucks up the dissolved tissues through this tube.

chiggers are encountered in grassy areas or in the transitional zone between fields and woods, and in other situations which furnish shelter for the wild animal hosts. Amphibians, reptiles, birds, and rodents are important hosts for the chigger. The important pests of man in the Americas are *Trombicula batatas*, *T. lewisi*, *T. göldii*, and *T. alfreddugèsi*. *T. autumnalis* is the common species attacking man in Europe. In the Australasian region, the Orient, and India the two most important species on man are *T. akamushi* and *T. deliensis*; these are very closely related and may be varieties of a single species.

In former years, flowers of sulphur were used liberally in the clothing to protect against chigger bites, and on lawns, etc., to kill the mites in the grass. More effective chemicals were discovered during World War II.

Dimethyl phthalate, dibutyl phthalate, dimethyl carbate, indalone benzyl benzoate and Rutgers 612 will protect against chigger attack when used either alone or in combination, as in the 6-2-2 formula. Travis and his associates also recommend the following formulae as being effective against mites and a wide range of insects:

Dimethyl phthalate	. . . . .	1 part
Rutgers 612	. . . . .	1 part
Indalone	. . . . .	1 part
Dimethyl phthalate	. . . . .	3 parts
Indalone	. . . . .	1 part
Dimethyl carbate	. . . . .	1 part

Diphenyl carbonate and benzil are also effective against mites; these materials are solids, and must be used with a suitable solvent.

These materials act as miticides rather than as repellents when used against chiggers. Dibutyl phthalate is slower in its action, and so does not protect so completely as do the other materials.

Miticides are applied to the clothing rather than to the skin. The outer clothing—trousers and shirts or jackets—and socks may be impregnated with about two ounces of the above materials, or one-fifth ounce of toxicant per square foot. The clothing may be dipped into a solution of the toxicants in dry cleaning fluid; about one and one-half quarts containing the two ounces of miticide is required for an ordinary set of clothing. Travis and his associates state that benzyl benzoate, benzil, diphenyl carbonate are preferable for the impregnation of clothing, as they are long lasting. Benzyl benzoate-treated clothing is still effective after two home washings, while those impregnated with benzil and diphenyl carbonate will last at least five washings.

Clothing may also be impregnated by dipping in an emulsion of the miticides. Emulsions can be made with soap, but the most convenient way to do so is to make a concentrate by adding 10 parts of a commercial emulsifying agent to 90 parts of the toxicant. This is diluted at the rate of one-half pint of the concentrate per gallon of water. After wetting the clothing, they are wrung out lightly and dried before being used.

Clothing may be impregnated by being sprayed with the materials. For individual protection against chiggers, perhaps the most convenient method is to apply the liquid preparations to the clothing by hand. Particular attention should



be given to the openings of the clothing; a barrier of miticide about a half inch wide should be placed around the cuffs, waistband, and fly of the trousers, cuffs, collar, and fly of the shirt; and on the socks. The material may be rubbed in by hand, or applied directly from the bottle by drawing the mouth of the bottle along the margins of the openings of the clothing.

Area control of chiggers for a period of 30 days has been obtained by dusting or spraying breeding areas at the rate of 10 pounds of benzene hexachloride per acre.

**Order Araneida. The spiders.** The only spider whose bite may have serious consequences in man is the black widow spider, *Latrodectus*. *L. mactans* is widely spread in the United States, and may be recognized by the red or yellow hourglass-shaped marking on the underside of the abdomen of the female. The female's abdomen is about the size of an ordinary marble and, aside from the red or yellow markings, is jet black in color. The female spins her web in various sorts of protected sites, between rocks, in hollow trees, and the like, and the webs frequently are placed in dark corners of basements, outhouses, and beneath porches and seats. People are bitten when they disturb the arachnid. The bite may or may not be felt as a sharp prick. The poison, a neurotoxin, spreads rapidly throughout the body and within a few minutes or a few hours there may be dull aching muscular pains all over the body, or extremely severe pains accompanied by cramps and spasms in the larger muscles, causing the victim to writhe in agony. The abdomen becomes rigid and board-like, so that misdiagnoses of surgical abdomen are said to be common. There is difficulty in breathing, low fever, and brachycardia. Amnesia has been reported as a sequela. A number of deaths have been reported as having been due to the bite of the black widow. Although most healthy individuals would probably recover without treatment, the response to the bite is dependent upon the amount of poison injected as well as upon the physical condition of the victim. No case should be treated lightly. The treatment of choice appears to be the intramuscular or intravenous injection of 10 ml. of 10 per cent calcium gluconate solution, accompanied by hot baths or hot packs. Magnesium sulphate, 20 ml. of a 10 per cent solution, given intravenously, is another treatment that has had considerable use. Thorpe and Woodson (1945) discuss the problem of arachnidism in detail.

The large, vicious-looking, hairy tarantulas are said to be gentle creatures which seldom can be induced to bite, and when they do, the bite may be painful but produces only local effects.

**Scorpionida. The scorpions.** The appearance of these arachnids, with the powerful pincers and caudal sting, are familiar to all. They are nocturnal and hide by day beneath logs, rocks, etc., but may also get into houses. Most scorpions are relatively harmless; their stings may be painful but result only in a local reaction similar to that caused by the sting of a wasp, but in Mexico, North and South Africa, Asia, and India there are certain species which are able to cause death in man. Fatal cases occur principally in small children. The poison has been described as being a neurotoxin and hemolysin which produces muscular cramps, pyrexia, profuse perspiration, vomiting, hemorrhages of the stomach, intestine, and lungs, and increasingly severe convulsions. Basu (1939) reports that the cases he observed

ia manifested symptoms of allergy; death took place immediately, due to or in those who outlived shock, to edema of the lungs.

The most effective treatment is the use of anti-scorpion serum. Symptomatic treatment employed by Basu included hypodermic injections of morphia, application of hot packs or hot baths to the extremities, and administration of saline, glucamphor or ether and adrenaline. Stahnke (1950) found that the most successful treatment for the sting of the deadly *Centruroides* in Arizona was immediate application of a tourniquet and immersion of the affected hand or foot in ice bath for two hours. The tourniquet is removed five minutes after the hand or foot is placed in the ice bath. He recommends sedation only after convulsions have

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# 8

## CONTROL OF RATS AND OTHER RODENTS

DAVID E. DAVIS, PH.D.

Rats and other rodents are the reservoir and source of several diseases of which plague is the most serious and widespread. A study, therefore, of habits and methods of suppression of rats, mice, and ground squirrels has become an important chapter in preventive medicine. In addition to their role in plague, rats are a source of leptospirosis, salmonellosis, murine typhus, and trichinosis as well as hosts of other parasites and infections which may be transmitted to man.

Rodents comprise more than one third of all living species of mammals and exceed any other mammalian order in the number of individuals. They have no canine teeth, but strongly developed incisors. Only the front of the incisors is covered with enamel, which keeps them sharp and chisel-like, owing to the more rapid wearing away of the softer dentine. The incisor teeth continue to grow throughout the life of the animal. The most extensive family of rodents is the Muridae which is divided into several subfamilies. Mice, *Mus*, and rats, *Rattus*, belong to the subfamily Murinae which is, therefore, the most important in preventive medicine. Mice can be distinguished from rats by their smaller size and the presence of a notch on the inner side of the upper incisors.

There are many different species of rats and mice, most of which remain indigenous and local; but there are three species that follow man to all parts of the world. These cosmopolitan murine rodents are the common house mouse, *Mus musculus*; the roof rat, *Rattus rattus*; and the Norway or brown rat, *Rattus norvegicus*.

**Description.** The different species of rats are identified by their color; length of ears, body, tail, and hind feet; shape of head; texture of pelage; number of mammae; and by the skull and teeth. *Rattus norvegicus* is easily differentiated from the *Rattus rattus* group by its larger size, more blunt muzzle, shorter ears which do not extend below the eyes when pulled downward, a thicker and shorter tail which is generally not as long as the body and has a less distinct ring-like appearance to the scaly covering, especially on the under surface. *Rattus norvegicus* females have 12 mammae, while *Rattus rattus* have but 10. There are other members of the genus *Rattus* with only 8.

The *Rattus rattus* group contains many subspecies and closely allied species, especially in the Malaysian region. For adequate identification, skins and skulls should be sent to a museum for comparison with named specimens. Three subspecies of roof rats (*R. r. rattus*, black; *R. r. alexandrinus*, brown with gray belly;



*R. r. frugivorus*, brown with white belly) have been introduced to many parts of the world and freely interbreed.

Albinism and melanism occur in all species; pied forms may occur. The white rat of the laboratory is an albino form of *Rattus norvegicus*.

**Distribution.** The genus *Rattus* contains more than 250 species and several hundred subspecies. The principal populations are in Asia and Malaysia. The Norway rats and roof rats have spread naturally throughout Europe and by means of man to practically every country and island in the world. The roof rats are generally limited to tropical and subtropical regions; or, when in northern regions, to the interior of buildings. Norway rats are distributed throughout the world but are found only locally in the Arctic and northern part of the temperate region. House mice also have a world-wide distribution. All three species have become feral in many parts of North and South America and live under wild conditions.

**Habits.** Roof rats, when present in conjunction with the more vicious and larger Norway rats, usually nest in the upper parts of buildings but in localities where members of the larger species are few or absent, roof rats will be found in large numbers in nesting places under buildings and in burrows or in the same harborage places generally preferred by Norway rats. In tropical climates, roof rats often nest in trees. Although Norway rats seem to prefer underground nesting places, their nests may frequently be found inside of buildings even in the upper parts of them when so constructed that they afford abundant rat harborage.

In mild climates, all of the cosmopolitan rodent species, even the house mouse will be found infesting the fields and brush considerable distances from buildings. Roof rats have a greater tendency to an exterior existence than the other species while Norway rats seem to have greater preference for the vicinity of buildings. Most species of rats live entirely outside of buildings.

Norway rats are not as agile as the other species and are less expert climbers. In the open, rats seem to have defective vision and by daylight move slowly and uncertainly; on the contrary, in contact with the wall, they run with great speed. This fact suggests that the vibrissae (whiskers) serve as feelers, and that the sense of touch in them is extremely delicate. Rats prefer narrow places and overhead pipes and beams as highways, and habitually follow the same course to such an extent that these highways or runs can be detected easily by the dark, greasy trail they make. The finding of runs is useful in locating rat hiding places and in discovering defects that allow passage to hiding and nesting places; and also as valuable guides for placing traps.

**Movements.** Extensive migrations of rats have been reported but their size has been exaggerated. The report (Pallas) that in the autumn of 1772 Norway rats arrived from the East at Astrakhan, southeastern Russia, in such great numbers and so suddenly that nothing could be done to oppose them has been discredited. It is claimed that in 1903 a multitude of migrating rats spread over several counties of western Illinois, traveling in great armies and causing heavy losses. Over 300 were killed in a month on one farm. Such migrations have not been observed to occur as the result of plague among rats.

Several movements of rats from houses and barns to the fields take place in the spring with the crops, and there is a return in the fall. This seasonal migration has been noticed in large cities.

The seasonal prevalence of plague is due in part to the seasonal movements of rats, but the large migrating movements have not been connected with the prevalence of the disease.

**HOME RANGE.** Rats, like other mammals, tend to remain within a limited area called a home range, for long periods of time. In Egypt, roof rats and another semisocial rodent were found rarely to leave the native houses (Petrie and Todd, 1911). Norway rats in the city of Baltimore rarely leave the block. By marking, tagging, and recapturing rats it was found that about 75 per cent of the recaptures were within 40 feet of the previous capture. Furthermore, on a farm, 90 per cent of the recaptures were within 40 feet (Davis and others, 1948). In Hawaii, Spencer and Davis (1950) found that three species of rats have limited movements. House mice live within an area of only 10 to 20 feet in diameter (Long and others, 1950). In general, it may be concluded that an individual rat will live for many months within a limited area unless there are radical changes in sanitary conditions. In urban residential areas the diameter of the home range will be about 100 to 150 feet.

When rats are introduced into an area, the probability of dying is very high (Davis, 1953), and no appreciable increase in population occurs in the area until reproduction has kept the area population at the saturation point. The work of Creel (1915) showed that rats liberated in a strange place will travel long distances in search of a new home. However, after a rat has found a suitable place, it will remain within a small area for many months or until there is a change in the environment.

**ON VESSELS.** A few years ago rats were present on all vessels and the three cosmopolitan species had been spread to all parts of the world by sea. Norway rats are much less commonly encountered on vessels than the other species; they never exceed over 1 per cent of rats killed by fumigation at United States quarantine stations. Rats have easy access to vessels as they lie at dock; many rats are probably stowed aboard in cargo.

At the present time, it is almost a universal procedure to include rat proofing as a standard requirement in contracts for new ships, both in American and in foreign shipyards. Many old vessels have also instituted measures that make them relatively rat proof. These procedures have markedly reduced the rat infestation on many ships and consequently lessened the dangers from rat-borne diseases.

It is important to prevent the introduction of rats on vessels at plague-infected ports; it is also important to prevent the passage of rats from ship to shore, particularly if the vessel is from a plague port. In extreme cases the ship should not approach the dock, but cargo should be handled during daylight by means of rat-proof lighters. Cargo which might harbor rats should be inspected, sometimes opened and repacked, or fumigated. Vessels from plague-infected ports found by inspection to be rat infested at time of arrival should be fumigated at once, whether empty or loaded, and rats that are killed by fumigation should be examined for evidence of plague. Cargo of such vessels should be inspected as discharged to determine that it is not harboring rats.

Measures that reduce the probability of rats entering and leaving vessels are: the use of rat guards on all lines connecting ship with shore and idle lighters; guarding gangways during the day and raising them or lighting and guarding



them at night; removing cargo slings and other gear connecting with shore and not in use; and fending vessels six feet from wharves. Periodic rat-infestation inspections of vessels, with fumigation only when found infested, is a measure being universally adopted to displace the old procedure of periodic fumigation on vessels that trade at clean ports.

**Food.** Rats are omnivorous but as a group grains are their food of choice. Rats prefer fruits. Rats are like man in that they learn to eat the foods of the locality in which they live and will often ignore foods selected by rats in other places. On the other hand, those of the same species and locality show great divergence in their choice of foods. Most rats will take fresh meat. Bacon mixed with grain is the best bait. In the tropics, fresh cocoanut is one of the most effective baits that can be used. Starved rats will eat anything but this fact cannot be relied upon to bring results when preparing rat baits.

**Economic Importance.** The destruction of food, crops, merchandise, and property by rats is so great that this alone would justify active measures of suppression even though they were not responsible for human disease. Rats destroy growing grain, vegetable and other crops; they invade stores, destroy flowers, laces, silks, carpets, and eat fruits, vegetables, meats, etc., in markets; they destroy by pollution ten times more than they eat; they gnaw lead pipes and floors of houses; they ruin artificial ponds and embankments by burrowing; they destroy eggs and young poultry; they damage foundations and piers; in short, they have become the worst mammalian pest among us. Rats actually destroy more eggs, chickens, and game than all the wild animals combined.

The number of rats in an area may vary greatly according to conditions. A farm may have several thousand. Davis (1950) estimated about one rat for every 10 people in New York City; Brown and others (1955) one for 8 people in Baltimore.

**Reproductive Rate.** The number of young produced depends upon the environmental conditions and the stage of growth of the population. The reproductive rate is partially dependent upon the level of the population in respect to the carrying capacity of the area to support rats. Rats reproduce at all seasons of the year although in many areas there is a maximum in both spring and fall. The percentage of adult females that are pregnant varies from 18 to 40, depending upon location, age of female, season, and population growth phase. The annual incidence of pregnancy (number of pregnancies per year) varies from four to eight, according to locality. For rat control purposes the incidence of lactation is a more useful rate since it indicates how many litters are about to be weaned. The meager data available indicate an annual incidence of two to four per year. The number of young weaned at each lactation is probably about seven in Norway rats, since there is a loss of about 30 per cent of the embryos at parturition and during lactation. As a generalization, it can be said that the average female Norway rat weans about 20 rats per year (seven weanlings  $\times$  three litters) (Davis, 1951).

**Mortality Rates.** The annual death rate in an average rat population is about three rats per rat in the population, and the annual probability of dying for an individual is about 0.95 (Davis, 1953). For very young rats (weanlings) the death rate is about nine and the probability of dying within one year is at least 0.99. Females probably live longer than do males. However, there may be great variation from place to place, or from year to year (Davis, 1951). The available

ence suggests that population changes depend more upon changes in death than upon changes in birth rates.

**Rat Populations.** Since the spread and transmission of disease and the control best depend upon the characteristics of a population, it is important to describe behavior of a group of rats in contrast to the habits of the individual. After a reduction in numbers, a population grows logistically (Emlen and others, 1948) until it becomes stationary at a level that is determined by the capacity of the area to support rats. Killing procedures (poisons, traps, cats, etc.) are rarely sufficiently effective to keep the population at a low level. Actually, these procedures as generally practiced merely make room for other rats to grow up. The limitation of the population comes about by means of competition among rats for the amount of food and harborage available. Fierce fighting permits a few rats to dominate the others. These high-ranking rats feed and reproduce approximately normally but inhibit the growth and reproduction of the inferior individuals. The population, therefore, becomes stationary at a level determined by the environment.

The history of the rat population of a block in Baltimore illustrates the characteristics mentioned above. The population estimates were made by the method

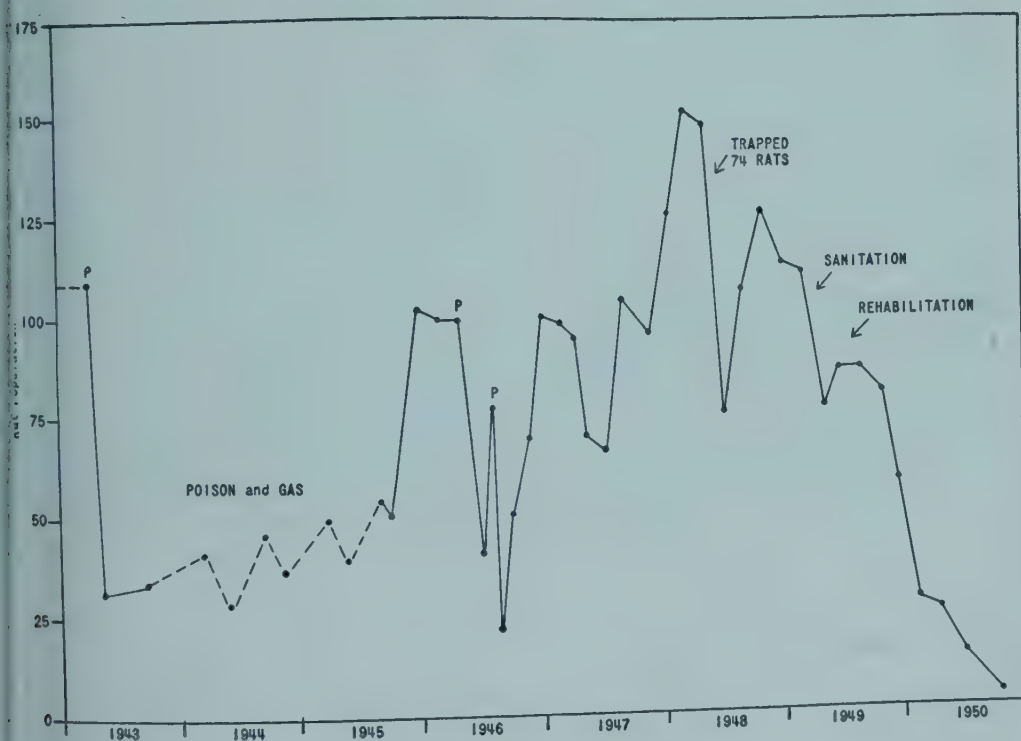


Fig. 8-1. History of rat population in Baltimore, 1943 to 1950.

Emlen and others (1949). All rat signs, such as holes, feces, tracks, etc., were recorded on a detailed scale map of the block. Then from these signs an estimate of the rats was made that was based upon a calibration from rat signs to rats trapped in a variety of places. The method has an error of about 10 per cent. In 1943, the block contained about 113 rats. An intensive experimental poisoning and gassing program by volunteers kept the population reduced for several years but could not be maintained because of the excessive cost. The population rapidly returned to about the same level as in 1943 and remained for four months



at that level. Two more poisoning campaigns temporarily reduced the population but it returned promptly to the level of 100 rats. Then, in early 1947, the population declined for no detectable reason and subsequently rose to a peak of 150 rats. This increase apparently was the result of an increase of the capacity of the block due to very poor sanitary conditions. The trapping of 74 rats temporarily reduced the population. In late 1948, sanitation and housing laws were enforced and the population has declined to only a few rats.

This history is an example of an accumulation of data (Davis, in preparation) that permit several conclusions: (1) even very intensive poisoning campaigns reduce the population only temporarily; (2) a population will increase to the capacity of the block to support rats and then remain at that level; (3) sanitation and rehabilitation will reduce the rat population drastically.



Courtesy Baltimore City Health Department

Fig. 8-2. Housing conditions before rehabilitation.

**Control.** The control of rodent population should be based on an alteration of the sanitary and other environmental conditions so that the rodents have neither food nor shelter. Competition among the individuals will reduce the population. In many cities striking reductions have resulted from sanitation and rat proofing and in some places without any killing procedures whatsoever (Davis, 1951). The fundamental points are: (1) it is administratively feasible to alter the environment enough to reduce the rats; (2) subsequent insanitary conditions develop slowly and can be checked by inspections; and (3) the results are improved living conditions for human beings and rat control. In contrast, killing procedures only reduce the population to a low level since the rats increase rapidly. Furthermore, the effort and money does not improve other living and sanitary conditions.

The details of control procedures are given in the publication of the U. S. Public

h Service entitled "Rat-borne Disease. Prevention and Control" published by Communicable Disease Center, Atlanta, Georgia. The following paragraphs summarize some of the important aspects.

**REHABILITATION.** Recently, rat control has developed into a phase of a better housing program, called rehabilitation. A procedure of inspection and law enforcement results in improvement of sanitation, plumbing, floors, cellars, and the buildings themselves. As an incidental but important part of this program the rats are eliminated. Rehabilitation is applied primarily to dwellings and has the same effect of improving housing conditions.



Courtesy Baltimore City Health Department

Fig. 8-3. Housing conditions after rehabilitation. Note removal of fences and trash.

**RAT PROOFING.** Rat proofing is applied primarily to commercial structures and is designed to prevent rats from doing economic damage. It is relatively permanent. However, rat-proof structures may become infested if the rats are allowed entrance, provided shelter, and provided food. Rats enter through drain pipes if left open; through doors, especially from alleys; and through basement windows. The lower parts of the outer doors of public structures, such as markets and wharves, should be tight fitting and reinforced with metal to keep the rats from gnawing through. Basement windows should be screened and doors provided with springs to keep them closed. The special points of ingress and egress of rats which must be guarded are hatches, ventilators, skylights, unused chimney flues, and openings around sewer, sewer, gas and steam pipes, and electric wires. Screens should be placed in tunnels and other strategic places to prevent rats wandering from one place to another in large groups of buildings and on ships.

Foundation walls should be laid without a break around the entire building and should extend not less than 18 inches beneath the surface of the surrounding ground, and should always be flush with the under surface of the floor above. Floor



joists should be imbedded in the wall or the spaces between the joists filled in and completely closed up to the floor level. Ground areas should be concreted with a layer at least three inches in thickness, finished with a wearing surface of cement about one-half inch thick. The walls of a wooden house should have one foot of concrete between the sheathing and lathing. All water and drain pipes should be surrounded by concrete where they pierce the walls. Rat holes may be closed with a mixture of cement, sand and broken glass, or sharp bits of crockery and stone.

Buildings may be raised 18 inches or more from the surface of the ground on piers, thus reducing rat haborage under them. Cribs for grain in the country may be raised and further protected with metal netting.

The chief refuges for rats in cities are provision houses, markets, warehouse slaughterhouses, restaurants, bakery shops, candy factories, and dwellings. In the country it is important to build corn cribs, barns, and granaries rat proofed with the wise use of cement, iron sheeting, or galvanized iron netting. The field rats of the tropics cannot be controlled by rat proofing for there is a continual abundance of exterior food.

**STARVING.** A scarcity of food is of utmost importance in assisting other suppressive measures. Garbage and offal must be disposed of so that rats cannot get at such stuff. Well-covered garbage cans should be required and the garbage frequently removed and burned. Slaughterhouses are centers of rat propagation. The offal is best disposed of by burning. Produce in provision stores may be protected by wire screens. Care should be taken also as to the disposal of remnants of lunches in office buildings and the disposal of organic waste generally.

**TRAPS.** Snap and cage traps are usually employed in most rat suppression campaigns. Snap traps are much cheaper, more easily handled, and possibly more efficient so that they have become the type most generally used. When placed in runs they may catch rats not concerned with their bait. When live rats are desired it is necessary to use cage traps. They should also be employed where there is danger of children, chickens, domestic animals, and wild birds being caught in the snap traps. The most efficient bait for any given locality is best determined by experimental trials. Bacon, fish heads, grains, fresh vegetables, fruits and, in the tropics, cocoanut are generally good baits. It requires ingenuity to trap rats.

**POISONS.** Killing procedures have in the past had great popularity because of their ease of application and their visible results. At the present time, poisoning is still widely practiced but with limited results except in some special areas. The use of poisons is worth while as a temporary measure in dumps, certain types of public housing, and for feral populations.

Some of the older poisons are still widely used. Red Squill is a favorite because its emetic action protects animals that can vomit. Strychnine, thallium, and arsenic are sometimes used but are somewhat dangerous. Barium carbonate and phosphorus are seldom used because of their erratic results.

In recent years, a number of new rodenticides have been developed. **ANTHRA** is specific for Norway rats but kills dogs and does not kill roof rats. Sodium fluoroacetate (1080) is a powerful poison for every animal and has been prohibited in many places because of human deaths. Warfarin (a derivative of dicumarol) is an anticoagulant that has a large safety factor because of the very low dose (0.1 per cent) that must be taken for four days to kill rats.

of these poisons require safety precautions and give only temporary results. It should also be mentioned that cultures of *Salmonella* (usually called rat viruses) had little effect on rat numbers and are obviously a hazard to public health.

**NATURAL ENEMIES.** The natural enemies of the rat are the larger hawks, owls, skunks, foxes, coyotes, weasels, mongooses, minks, dogs, cats, and ferrets. None of these animals is of value in rat eradication campaigns, although all of them help keep the rat population down to some extent. The mongoose (*Herpestes eremicus*) was introduced into the Hawaiian Islands from Jamaica in 1883 to destroy rats and is now present in great numbers. Although they no doubt have destroyed many rodents, the results have been far from satisfactory as they have had no general reduction in the number of rats but have destroyed many chickens and birds.

**FUMIGATION.** Rats may be killed with certainty in any inclosed structure by the use of sulphur dioxide, carbon disulphide, hydrocyanic acid gas, or carbon monoxide, provided all enclosed spaces are opened to allow penetration of the gas. Hydrocyanic acid gas is gradually displacing the use of sulphur dioxide in the fumigation of vessels. In the days before periodic fumigation was required and before the introduction of rat proofing, enormous numbers of rats were commonly found in the fumigation of ships. For instance, the S.S. Minnehaha, a vessel only 18 months in commission, fumigated in London in May, 1901, yielded a bag of 100 rats. Such an incidence could not occur with a modernly constructed rat-proof ship.

In conclusion, it is possible to control rats by removal of harborage and reduction of food supply. Adequate biological knowledge is available to permit intelligent planning of control measures, especially for Norway rats. Administrative details of problems differ from place to place and may require some effort for solution.

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## 9

### DISEASES SPREAD LARGELY BY CONTACT WITH ANIMAL OR OTHER EXTRAHUMAN SOURCES

#### ANTHRAX

(*Splenic Fever; Charbon*)

Anthrax has figured prominently in the history of bacteriology and immunology. Anthrax was the first pathogenic bacillus to be seen under the microscope, by Pollender in 1849. Anthrax was the first communicable infection to be experimentally transferred, when Davaine and Rayer, in 1850, communicated splenic fever by the direct inoculation of blood containing these "infusoria" to susceptible animals. This established the etiological significance of the organism which they found in the blood of the sheep which they infected. Pasteur studied the disease and observed the multiplication of the bacilli under the microscope. He also grew the organism on coagulated blood derived from infected animals. Anthrax was the first bacterium to be grown in pure culture by Koch, in 1875. This was not only the first, but a convincing demonstration of the use of solid medium and the plate method for the isolation of pure cultures. Anthrax was the first dramatic demonstration by Pasteur, in 1881, of the prophylactic value of an attenuated virus. Pasteur's achievements in protecting sheep against anthrax closely followed similar laboratory experiments upon fowl cholera. The disease itself has long been known and has been recognized from early times. One of the best descriptions of an early epidemic of anthrax was by Athanasius Kircher, a Jesuit, who, in 1658, described an outbreak among cattle, occurring in 1617, which later spread to man, claiming about 600 victims.

Anthrax belongs to that group of infections which occur primarily in the lower animals and secondarily in man. The infection is found especially in cattle and horses, but also in sheep and other cloven-hoofed animals, and may be transmitted experimentally to mice, guinea pigs, rats and rabbits. Cold-blooded animals and birds, as well as dogs, are refractory. Zoologically, anthrax is one of the most widespread of infectious diseases. It is found in most parts of the world and in a large range of climates. In Siberia, where it has caused fearful destruction, it is still known as the Siberian "boil plague." Continental Europe has suffered much from its ravages, and it prevails in South America, Asia and Africa. In the U. S. it is a rare disease except in certain well-known infected areas where it exhibits permanent occurrence in animals. "Anthrax districts" have been recognized in southeastern South Dakota, northeastern Nebraska, part of the Texas Gulf Coast, and the lower Mississippi River Valley from Arkansas to and including the delta region (Stearns, 1942).

lateral outbreaks of animal anthrax in the Middle Western States during 1951-52 were traced to contaminated bone meal which had been imported.

**Human Anthrax.** In man the infection may enter the skin (*malignant pustule*) or the lungs (*wool-sorters' disease* or *rag-sorters' disease*) or may infect the digestive tract and produce intestinal lesions. The infection sometimes localizes in the brain and meninges.

In anthrax of the skin the infection usually enters through slight abrasions, scratches, or small wounds, especially on the forearm, hand, neck, or face. In hunters or persons who carry infected carcasses or hides, it is likely to occur on the neck and shoulders.

Many cases of anthrax in the United States and in England have been traced to shaving brushes made of horsehair. Vincent (1922) found anthrax spores in a shaving mug after the removal of the brush.

**Cutaneous Anthrax.** The cutaneous lesion (*malignant pustule*) has a characteristic evolution and appearance. It begins as a small, red, indurated area, in the center of which a vesicle develops. As it increases in size, satellite vesicles appear. The surrounding tissues become edematous. The center of the lesion softens and becomes necrotic and a characteristic dark brown eschar is formed. The lesion is painful. The regional lymph glands become swollen and tender. Malaise, fever, and general prostration develop in varying degrees. Regression may begin at any time. In 5 to 10 per cent of cases there is a progressive cellulitis, sepsis and shock.

*Wool-sorters' disease*, or anthrax of the lungs, appears to be due to the inhalation of anthrax spores. It is observed only among persons who handle skins or who work with horsehair, wool, or other raw materials from animals afflicted with anthrax. The symptoms are like those of pneumonia; this form is frequently fatal. Although the usual heat of cooking does not necessarily kill spores, in the United States there is no report of the transmission of anthrax to man by meat or milk. Intestinal anthrax is rare, but when it does occur it is rapidly fatal. The anthrax spore is exceedingly resistant to heat and external influences such as drying and sunlight, and also to germicidal agents.

**Prevalence.** In the United States human anthrax is mostly an industrial disease contracted through the handling of skins, hair or the animals themselves. Those especially exposed to the hazard are laboratory workers, veterinarians, meat inspectors, farmers, cattlemen and butchers, but especially workers with hides, hair, wool, etc. Of about 1,000 men exposed to the danger in Pennsylvania tanneries, 123 in all contracted anthrax in the course of 12 years, or more than 11 per cent of the number of directly exposed tanners. Seventy-three of these cases were due to the handling of cattle hides and 50 to the handling of goat hides. One fifth of the cases died (Smyth and Bricker, 1922). A special inquiry (Smyth and Higgins, 1945) revealed the occurrence of 408 human cases of anthrax in the five-year period 1939 to 1943. Information regarding the probable source of infection was obtained on all but eleven. In 20 per cent it was classified as due to handling of hides and skins, in 60 per cent to contact with wool or hair, in 16 per cent to direct contact with infected animals or soil (agricultural), and in the remaining 4 per cent to other miscellaneous sources. From 1945 to 1951 from 40 to 60 human cases were reported each year.



The causative organism is recovered and identified by inoculation of mice with material from the lesion, blood, tissues, or articles suspected of being contaminated; this technic screens out nonpathogenic contaminants.

An immune serum, made by inoculating horses with virulent anthrax bacilli, has been used in treatment. It is injected locally as well as intravenously. More recently, treatment with penicillin seems to be quite effective (Ellingson and others, 1946) and would seem to be the method of choice for many reasons.

**Control in Animals.** The prevention of the disease in man must first be directed to a suppression of the infection in animals by veterinary measures of control. Sick animals should be isolated, or, better, killed, and the carcasses burned or buried with lime at least six feet deep. The cadavers may be "tanked," that is, subjected to a prolonged exposure to steam under pressure. Tanks for this purpose are found in all the larger slaughter houses. It is important in handling the body of an animal dead of anthrax not to open it or shed blood, for the bacillus does not produce its spore except in the presence of oxygen; that is, the bacilli in the blood and internal organs will not sporulate as long as access to the air is prevented.

The neglect of precautions in disposing of anthrax carcasses favors the spread of the infection through the activity of carrion feeders. Buzzards may carry infection for long distances and contaminate clean ground or water through contamination on their feet and beaks. Dogs discharge anthrax spores in their feces 114 hours after feeding upon an anthrax carcass.

Anthrax spores may live months, even years, in the soil. Hastings (1923) found anthrax spores in a pond in a pasture in which the disease had occurred eight and one-half years before.

When an outbreak of anthrax occurs in a dairy herd, the herd should be quarantined under supervision of the state livestock sanitary authority until 10 days after the appearance of the last case. The milk during this period should not be used. Recommended procedures for control of anthrax in a dairy herd have been formulated in detail by the U. S. Public Health Service (Steele and Helvering, 1953).

**Vaccination of Animals.** That animals could be immunized against anthrax was demonstrated by the world renowned experiment which Pasteur conducted at Pouilly-le-Fort in 1881. With his associates, Roux and Chamberland, he found that when a virulent strain of anthrax was grown in broth at a temperature of 42° C to 43° C it was progressively decreased in virulence. For immunization purposes he prepared two types of vaccine. He injected first, fresh bouillon culture of a strain so attenuated that it was fatal for mice only and not for guinea pigs or rabbits (Pasteur No. 1). Twelve days later, he injected a less attenuated strain (which would kill mice and guinea pigs but not rabbits) (Pasteur No. 2). This method was subsequently used on a large scale and was a tremendous factor in the control of anthrax in animal herds. It was used on cattle, horses, mules, sheep, and goats. In practical use, however, it was not altogether satisfactory. A small percentage of the animals succumbed as a result of the vaccination. It required handling the animals twice. As the anthrax vaccine was actually a bouillon culture of the organism, it tended to become inert through autolysis if kept for any period of time. As these shortcomings became apparent, efforts to improve the method of vaccination were made and have continued up to the present time. In 1902, Sol

recommended a modification in which anti-anthrax serum was injected subcutaneously on one side of the body followed immediately by injection on the other side of a single dose of Pasteur's No. 2 anthrax vaccine. This method was later modified by Eichhorn (1925) in that a spore vaccine of the virulence of Pasteur's No. 2 strain was used in combination with a potent anti-anthrax serum. There are now a number of different types of vaccine commercially available. These include the spore vaccines given with or without simultaneous injection of serum, the vaccine injected intracutaneously, spore vaccine suspended in saponin, and the killed products (bacterins). Gochenour and others (1935) tested the effectiveness of a number of these products on sheep. In brief, it was found that all the types of the last mentioned type confer a considerable degree of immunity without causing any animal losses. None, however, affords complete protection in all the animals vaccinated.

While veterinary measures are effective in suppressing outbreaks of anthrax among animal stocks, there is no way of permanently eradicating the organism from the soil and vegetative cover of an infected area. Nor can the introduction of infection into new areas by the movement of livestock and the shipment of animal products such as hides, wool and hair be entirely prevented. Efforts to prevent the exposure of human beings to infection by regulations requiring an embargo upon importation of hair and bristles from suspected areas, and areas in which information is lacking, have not proved to be satisfactory. Enforcement is difficult or impossible. The prevention of human infections must be based on the concept that there is a potential hazard to persons employed in occupations which bring them into contact with animals or animal products. This hazard should be minimized so far as practicable.

The sale of hides from animals known to be infected with anthrax should be prohibited unless they have been subjected to a satisfactory disinfection process. Disinfection of hair and bristles from sources known or suspected of being contaminated should be obligatory before they are used or sorted. Employees in tanneries, woolen mills and factories utilizing animal hair in bristles should be under medical supervision. Efforts should be made to reduce skin injuries by the use of mechanical aids in handling heavy items and by wearing gloves when handling hides. Emphasis should be placed upon prompt surgical treatment of all skin lesions and medical examination of all suspicious lesions. Proper ventilation should be provided to carry off the dust where hair and wool are handled, especially about carding machines. Trade wastes and effluents from such plants should be properly treated before being discharged into streams and rivers to avoid contamination of overflow land used for pasturage. Since no satisfactory nonliving vaccine is available, immunization of human beings is impractical. The low incidence of the disease among those exposed by occupation does not justify specific prophylactic measures.

**Disinfection.** Disinfection for anthrax is difficult on account of the extraordinary resistance of the anthrax spores. It is further complicated by the fact that dependable methods are apt to injure the hides.

Steam disinfection is practicable for hair, but not for wool or hides. The wool and hides are seriously damaged by the action of the steam. Wool may be disinfected by formaldehyde used as given below. The method preferred for hides



is the hydrochloric acid-salt bath of Schattenfroh. Manufacturers object to the disinfection of hides with bichloride of mercury and formic acid, according to the Seymour-Jones method, on account of the apparent injury caused by such treatment.

**HAIR FOR SHAVING BRUSHES.** The disinfection of the hair used for shaving and lather brushes is accomplished by one of the following methods: (a) by boiling the hair or bristles for not less than three hours; (b) by exposing the hair or bristles to steam under not less than 15 pounds' gauge pressure for not less than 30 minutes with a preliminary vacuum of not less than 10 inches before turning on the steam (Schneiter and Kolb, 1948); (c) by exposure to streaming steam for not less than six hours; (d) by dry heat, 200° F, for 24 hours.

**SHAVING BRUSHES.** Any brushes found in the market which do not bear the name or the trademark of the manufacturer should be regarded with suspicion and should be returned to the source from which they were secured, or should be disinfected. Shaving brushes will stand boiling or steaming. The following procedure is believed to be effective:

The brush should be soaked for four hours in a 10 per cent formaldehyde solution. The solution should be kept at a temperature of 110° F, and the brush agitated as to bring the solution into contact with all hair or bristles.

**WOOL.** The following method is recommended for the disinfection of wool, goat hair and camel hair. A preliminary agitation with an alkaline solution of soda in water at a temperature of 102° to 110° F; exposure for 20 minutes in a 2 to 2.5 per cent solution of formaldehyde in water at a temperature of 102° to 105° F. The hair is then dried in a current of air at 160° F, and allowed to stand a short time in order that the formaldehyde may complete its germicidal action.

**HIDES AND SKINS. The Seymour-Jones Method.** To one pound of perchloride of mercury add 500 gallons of water, and to this mixture add five gallons of formic acid (commercial 50 per cent strength). In this bath steep the material for 24 hours.

**The Schattenfroh Method.** In a 2 per cent hydrochloric acid solution to which 10 per cent of common salt has been added steep the material for 40 hours at a temperature of 60° to 70° C. A quicker method can be used by substituting a 1 per cent solution of hydrochloric acid and 8 per cent of salt, provided the temperature of the solution is maintained at 40° C (104° F) for a period of six hours.

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## BRUCELLOSIS

(*Undulant Fever, Malta Fever, Mediterranean Fever*)\*

Under a multitude of names, the human disease now generally known as *undulant fever* was differentiated during the latter part of the nineteenth century. The British Army Surgeon, Sir David Bruce, conducting studies on the Island of Malta in 1866-87, briefly described a "disease of long duration characterized clinically by continued fever, profuse perspiration, constipation, frequent collapses, rheumatic neuralgic pains, swelling of joints or orchitis." He isolated and identified the causative agent, which Hughes erroneously named several years later *Micrococcus melitensis*. Subsequent investigators, recognizing that the organism was not a bacillus but a pleomorphic bacillus, called it *Brucella melitensis*. The disease may be mistaken for typhoid fever, rheumatic fever or tularemia. Undulant fever is remarkable for its low mortality, recurrent attacks and long drawn out duration. The period of incubation is about two weeks but varies from one week to three weeks or possibly longer. A large proportion of infections is inapparent.

**Relationship between Undulant Fever and Contagious Abortion.** About 10 years after the British army surgeon Bruce disclosed the *Micrococcus melitensis* as the cause of Malta fever, Bang, a Danish veterinarian, discovered the cause of contagious abortion in cattle, which he called *Bacillus abortus*.

Two more unrelated diseases can hardly be imagined, yet Alice Evans (1918) discovered by ordinary laboratory methods that the Bang bacillus and the Bruce micro-organisms are indistinguishable. The observations of Evans were soon confirmed by her and Shaw (1920) and a number of investigators in other countries. Upon further study, Evans herself and others soon revealed a family group of closely related micro-organisms distinguishable from each other partly by their source and partly by absorption agglutination tests. This group is now called *Brucella* as a permanent memorial to the genius of its original discoverer.

**Brucella.** There are three species of *Brucella*: (1) caprine (*Sp. Br. melitensis*) causes the disease in goats; (2) porcine (*Sp. Br. suis*) causes the disease in hogs; (3) bovine (*Sp. Br. abortus*) causes the disease in cattle.

All three species may infect susceptible domestic animals or man. The caprine strain was the original organism of Bruce. It prevails widely among goats and is readily transmitted to man either through drinking goat's milk or handling the animals. It is the most pathogenic strain for man so far disclosed. The porcine strain causes abortion in hogs but is less serious for man. The bovine strain is the common cause of contagious abortion (Bang's disease) of cattle. Man seems to have a high degree of resistance to the abortus strain. During recent years, however, numerous cases of the human infection with this species have been recognized. Any one of the three types may infect goats, hogs or cattle and other species of domestic animals, particularly sheep, horses and dogs.

\* The disease is also known as febris undulans, febris sudoralis, Gibraltar, Neapolitan, Cretan, Cyprus or Danube fevers, abortus fever, melitensis septicemia, fièvre caprine, melitensis or Mediterranean phthisis, Munhinyo, goat fever, mountain fever, slow fever, Rio Grande fever, Bruce's septicemia, rock fever and Maltese fever. In 1913 the International Congress of Medicine agreed that the term *undulant fever* was the most satisfactory. Others prefer *brucellosis* for both man and animals.



**CHARACTERISTICS.** *Brucella* are small Gram-negative, coccobacilli occurring singly or in pairs, sometimes in short chains. The first generation of colonies in blood or urine develops slowly on artificial culture media. Minute dewdrop colonies appear after about four days of incubation, but cultures should not be discarded as negative until they have been incubated and observed frequently for two to three weeks. After having become established on ordinary media, they may be kept indefinitely by transplanting every six or eight weeks. *Melitensis* or *suis* strains grow well under ordinary atmospheric conditions, but for the *abortus* variety an atmosphere containing about 10 per cent of  $\text{CO}_2$  by volume is helpful if not essential for development. The three species are differentiated culturally by the bacteriological action of certain dyes by  $\text{H}_2\text{S}$  production and by glucose utilization. All three species are agglutinated by an antiserum prepared from any one of the three. Freshly isolated (S) strains of *Br. melitensis* can be distinguished from *Br. abortus* or *Br. suis* by careful agglutinin absorption technic.

**Laboratory Diagnosis.** There are five tests which are in general use: (1) cultivation and isolation of the organism from the blood, bone marrow, lymph nodes, joint effusions, urine, feces, exudates; (2) animal inoculation of suspected infectious material; (3) tests for allergy; (4) tests for serum agglutinins; (5) the opsonocytophagic test. The isolation of a pure culture of *Brucella sp.* from blood or tissues of patients or inoculated animals is the only means of proving the diagnosis. The reagents used in the intradermal test for allergy are suspensions of heat-killed *Br. abortus*, filtrates of old broth cultures ("melitin" or "abortin") and a nuclease protein extract ("brucellergin"). The interpretation of the test depends primarily upon the standardization of the material used. It should be employed in a dilution which will reveal specific sensitiveness with a minimum of nonspecific reactions. In a patient who is sensitive, both the local and the constitutional reaction may be severe. Read 48 hours after injection, with proper controls, a positive test is indicative of current or past experiences with *Brucella* organisms. An immune state may exist in the absence of skin allergy. This test is of questionable reliability in the diagnosis of chronic brucellosis. High agglutinating power sometimes develops in the blood of persons suffering from undulant fever. Titers of 1:5,000 are not uncommon. A titer of 1:80 or more is generally regarded as positive. On the other hand, the agglutinating power may be so low as to be misleading. The prozone phenomenon may constitute a source of error. A negative agglutination reaction does not exclude the diagnosis of undulant fever. Nor does a positive reaction necessarily indicate that the patient is suffering from brucellosis.

The opsonocytophagic test has been subjected to extensive evaluation; opinions vary as to its usefulness. It is unsuitable for routine diagnosis (Spink and others, 1952).

**RESISTANCE.** The *Brucella* genus is readily killed by heat. It succumbs in one hour at  $55^\circ\text{C}$ ; the majority die in 10 to 15 minutes at  $58^\circ\text{C}$ ; at  $60^\circ\text{C}$  all are killed. The thermal death point in milk is of practical importance. Temperature pasteurization ( $62^\circ$  to  $63^\circ\text{C}$ ) kill *Brucella* in three minutes. Phenol 1 per cent destroys the organism in 15 minutes. *Brucella* show remarkable resistance to dryness, and may remain alive for a month in dust. In damp manure they may survive 20 days.

**GOAT'S MILK AND MALTA FEVER.** We are indebted to the six reports of the British Commission for the Investigation of Mediterranean Fever (1905-07) for

undulant fever in Malta is spread chiefly through goat's milk. Before the  
es of this commission the common mode of infection was not definitely

usual source of milk in Malta was the goat. The udders, which are abnor-  
ng, often touch the ground and are liable to be soiled. It was first shown  
mit in the report of 1905 that goats could be infected by feeding them with  
*Brucella melitensis*. In the same year, Major Horrocks discovered *Brucella melitensis*  
milk of an apparently healthy goat. Further studies showed that one or more  
goats in every herd were excreting *Brucella melitensis* in their milk and  
nd that about 50 per cent of the goats reacted positively when examined by  
agglutination tests. All the available evidence points to their food as the main  
of infection in goats. The young goats, of course, are infected through their  
s milk. Horrocks and Kennedy considered that 10 per cent of the goats  
ng milk to various parts of Malta excreted *Brucella melitensis* in their milk.  
cretion of the specific micro-organisms may continue steadily for three months  
t any change occurring in the physical character or chemical composition of  
k and without the animal exhibiting any signs of ill health. On the other hand,  
cretion of *Brucella melitensis* in the milk may be intermittent, appearing for  
days and then disappearing for a week or more.

Major Horrocks in Report Number 5 of the British Commission shows a direct  
nship between the number of goats in Gibraltar and the number of cases of  
ant fever in man. With the reduction in the number of goats there was also a  
se in the number of cases of undulant fever, so that finally when the number  
ts had decreased to about 200, in 1905, the disease had practically disap-  
1.

he story of the steamship *Joshua Nicholson* is instructive. Sixty-one milch  
all healthy in appearance and good milkers (many being prize animals), and  
billygoats were shipped on board the cargo steamer *Joshua Nicholson* August  
1905, at Malta for passage to the United States via Antwerp. Many of the ship's  
any partook freely of the milk. The officers drank "mixed" milk collected in  
e vessel; the members of the crew each obtained the "whole" milk from one  
n his own separate pannikin. Subsequent bacteriological examination resulted  
e recovery of *Brucella melitensis* from the milk of several of the goats. Of 23  
on board who drank the milk on one or more occasions, no evidence whatever  
ailable as to 13; while of the remaining 10, nine suffered from febrile attacks,  
of them yielding conclusive evidence of infection with *Brucella melitensis*.

There is experimental evidence to show that monkeys can be infected by dry  
artificially contaminated with cultures of *Brucella melitensis*. The path of en-  
e may be through the nares, throat, respiratory passages, or alimentary canal.  
dust contaminated with the urine of cases of Malta fever has given rise to in-  
on in goats but not in monkeys. The experience gained during the work per-  
ed in Malta during 1904 and 1905 has convinced Horrocks that men are more  
eptible than monkeys and goats. Shaw's work on ambulatory cases among  
tese has also shown that opportunities for the infection of dust were plentiful  
Malta. Infected dry dust as a mode of transmission cannot, therefore, be discarded.  
There has long been a suspicion that undulant fever may be conveyed through  
bite of an ectoparasite; in fact, Captain Kennedy was able experimentally to



infect a monkey as a result of bites of mosquitoes (*Culex pipiens*) which had bitten patients suffering from Malta fever. This probably was an instance of mechanical transference of the infection, corresponding in all respects to a laboratory inoculation with fresh virulent material from a hypodermic syringe. This cannot be a frequent way by which the infection is transmitted in nature, for the specific organisms are found in small numbers in the peripheral blood of Malta fever patients. The British Commission found *Brucella melitensis* only four times from a total of 100 mosquitoes studied.

**Prevalence of Undulant Fever.** Recognition of brucellosis as a public health problem in the United States began with the finding by Craig (1905) of a case of undulant fever in a nurse who had never been out of the country. Gentry and Fenbaugh (1911) discovered a focus of cases in the goat raising section of Texas, along the Rio Grande River. An epidemic in Phoenix, Arizona, in 1922 was found by Watkins and Lake to be due to drinking unboiled goat's milk. Reports of cases giving a history of drinking unboiled goat's milk or being associated with the goat raising industry began to accumulate.

With the establishment of the true relationship of the *Micrococcus melitensis* of Bruce, and the *Bacillus abortus* of Bang, the origin of human cases from direct or indirect contact with cattle or hogs infected with contagious abortion was suspected and soon found. Keefer (1924), reported a case originating in Baltimore, Maryland, in which goat's milk could be entirely excluded as a cause.

By 1929, undulant fever had been recognized in every state of the United States. As differential diagnosis was better understood by physicians, the number of reported cases increased. During the four-year period 1942 to 1946, the median number reported annually for the country as a whole was 4,286. Incidence varied widely in different states, depending upon the state of development of the livestock industry and the spread of contagious abortion through herds of cattle, sheep, and hogs.

Similarly, in other countries as attention was directed toward the disease, undulant fever was found to be more common and widely distributed than had been suspected. It has become apparent that it may occur wherever goats, cattle, hogs, and sheep are domesticated. Areas in which it is known to be endemic are scattered throughout Canada, Mexico, the West Indies, portions of South America, Europe, Arabia, India, China, the Philippine Islands, and South Africa.

**Brucellosis in Cattle and Swine.** Approximately 5 per cent of the adult female cattle in the United States are infected with brucellosis. These infected cattle are confined to about 20 per cent of the herds throughout the country. It is estimated that the total annual loss from decreased milk production, fewer veal calves, and necessary replacement of dairy cows was approximately \$92,000,000 in the year 1947 (Spink and others, 1949).

When an infected animal is introduced into a susceptible herd an explosive epidemic may occur or the infection may spread insidiously from animal to animal over many months. Calves, up to the age of three and possibly six months, are relatively resistant to infection. During the first pregnancy is probably the period of greatest susceptibility. Not all infected animals abort. The spread of brucellosis to other animals is effected most commonly at the time of parturition or abortion and for two or three weeks following. The fetal membranes, chorion, fetus, and uterine discharges all contain brucella. There is a secondary localization of the organisms

teal ducts of the udder. Consequently, they are excreted in the milk of the cow. When the infection becomes established in the udder, it may persist for periods varying from a few weeks up to six or seven years or longer. Diagnosis is determined by a standard serum agglutination test. All animals showing a positive test are regarded as potential spreaders or carriers.

Brucellosis in swine occurs in various parts of this country but is not so widely distributed as in cattle. From packing house surveys it is estimated that the infection is present between 1 and 3 per cent. *Br. abortus*, the bovine type, has little or no virulence for swine and *Br. suis* is transmitted almost exclusively from pig to pig. In herds, the infection causes severe losses from abortion. For the most part it is a limiting disease. Many swine found infected by application of the serum agglutination test become negative within 90 days.

Although *Brucella* infections occasionally occur in other domestic animals (horses, dogs) they are relatively unimportant in the epidemiology of the disease in the United States.

**Modes of Transmission.** The two principal modes of transmission are by ingestion of raw milk or dairy products from diseased goats or cows, and by direct contact with infected animals in handling infected meat.

While the risk of contracting undulant fever from drinking goat's milk containing *Br. melitensis* is relatively great, a very low rate of human infection is usually found among the consumers of raw milk containing *Br. abortus*. Thus, Orr and Huddleson (1930) found in Michigan that in a group of 500 individuals equally divided into males and females of all ages, constantly exposed to the abortus organism through infected milk supply, only 1.4 per cent gave evidence of infection, and only 0.8 per cent showed any signs of active infection. The organism tends to concentrate in the cream layer. *Brucella* may survive as long as 25 days in butter and around two months in Roquefort cheese.

The frequency with which the disease is contracted by direct contact is reflected in the occupational selection for farmers, veterinarians, and workers in slaughterhouses, packing houses and butcher shops. Farmers and veterinarians are exposed to infection through contact with hogs and cattle in vaccinating, castrating, medicating, struggling animals, in the manual removal of placentas, and related procedures. On the basis of an epidemiological study of 354 cases of undulant fever in Iowa, Hensley and others (1930) estimated that approximately one-half were due to contact with infected animals, their tissues or discharges, the infection in all probability entering through cuts and small unnoticed abrasions of the skin. Of 420 strains of *Brucella* isolated from human cases and studied by Borts in the Iowa State Hygienic Laboratory, 62 per cent were *Br. suis*, 27 per cent *Br. abortus*, 12 per cent *Br. melitensis*. In a study of 268 cases in Minnesota, Magoffin and others (1949) concluded that approximately three fourths of all cases had had direct contact with infected animal material, but about one fourth of the patients presented no history of animal contact and had ingested raw milk. *Br. abortus* was isolated by blood culture from 86 per cent of these patients, *Br. melitensis* 8 per cent and *Br. suis* from 6 per cent.

Obviously, the epidemiological pattern with regard to age, sex, race, occupational selection, seasonal incidence, relative frequency of bovine, porcine and caprine strains, and other features will vary in different localities of this and other countries,



depending upon the character of the local animal husbandry, habits with regard to ingestion of raw milk and dairy products, and related factors.

Patients may excrete the organisms in the urine during the acute illness and sometimes during and after convalescence. Nevertheless, contact transmission from man to man is extremely rare. Where suspected, careful inquiry almost invariably reveals other more probable routes.

There are few diseases transmitted to laboratory workers so readily as undulant fever; in fact, most investigators contract it and are unable to trace their infection to any definite accident.

**Treatment.** The tetracycline antibiotics, especially aureomycin, usually induce subsidence of fever and other symptoms in several days, but the relapse rate is high. Administration of the drug should be continued for at least three weeks.

**Prevention.** The prevention of undulant fever due to the ingestion of milk or dairy products, whether from cows or goats, is a relatively simple matter. All milk, cream, cheese, butter, and ice cream should be properly pasteurized. Where pasteurization is not practicable milk should be boiled before use.

The prevention of undulant fever due to contact with animals or animal products is a much more difficult matter. Where brucellosis prevails among animal stocks, exposure of herdsmen, farmers, veterinarians, slaughter house employees, and butchers is inevitable. The hazard can be reduced somewhat by education. A safe and effective measure of artificial immunization with a vaccine suitable for human use has not been developed. Prophylaxis that would be fundamental and enduring consists in the elimination of brucellosis from domestic herds (Fleming and Roepke, 1949).

Experience of the past 50 years justifies the statement that brucellosis can be eradicated from any herd when the procedures best adapted to the particular herd are followed through under the direction of persons trained in the control of livestock diseases, provided the owner or caretaker of the animal gives his full cooperation. The recommendations of the Committee on Brucellosis of the U. S. Livestock Sanitary Association, the so-called National Plan, should be followed (Spink and others, 1949). These recommendations provide four different methods of procedure for the eradication of brucellosis from a herd of cattle. Principal dependence is placed upon two procedures: (1) the testing of animals for brucella agglutinins and elimination of reactors by slaughter, and (2) vaccination of calves or adults.

For vaccination a living attenuated strain of *Br. abortus*  $\pm 19$  is employed. From the studies which have thus far been made with strain  $\pm 19$  as the immunizing agent against bovine brucellosis, it is reasonable to conclude that when it is used on calves between the ages of four and eight months, sufficient immunity is developed to protect at least 90 per cent against developing brucellosis during the first pregnancy; a high degree of protection remains through the second and third pregnancies; this treatment of calves, nonpregnant heifers, and cows does not lead to the establishment of the injected organism in the animal body; the calves and young heifers show an agglutinin titer for only a few months after vaccination, thus eliminating confusion in the use of the agglutination test as a means of detecting active infection. By the use of such plans and procedures in the United States, the dairy herds in large areas have been rendered brucellosis free.

It has been found practical and economic to maintain herds of swine free from

brucellosis. Hog tight fences for pastures are required. All sows are tested and reactors eliminated. The remaining noninfected sows are bred only with tested boars. Thereafter, brood sows are reared in the protected herd. Similar measures may be employed in the management of goat herds.

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## GLANDERS

(Farcy)

Glanders is a widespread communicable disease of horses, mules, asses, and other animals, and is readily communicated to man. Cats may become infected by eating the flesh of glandered horses. Goats also have the disease. Cattle are immune. Guinea pigs and field mice are very susceptible by experimental methods; white mice have a natural immunity. In both man and horses, glanders is remarkable for its fatality. The disease is characterized by the formation of inflammatory nodules either in the mucous membrane of the nose (glanders) or in the skin (farcy). The nodules break down, leaving crater-like ulcers. On the skin the farcy buttons break down and discharge an oily material. The mortality is about 50 per cent. Glanders occurs both as an acute and chronic disease.

The infection may be introduced into the system either through the skin or mucous membrane, and is usually communicated directly from the horse to man by



contact with the infected discharges. The disease is sometimes communicated from man to man. Washerwomen have become infected from the clothes of a patient.

The bacillus of glanders, *Malleomyces mallei*, does not have a spore. It is comparatively frail and readily destroyed by the usual physical and chemical germicidal agencies used against spore-free bacteria. Its resistance corresponds to that of the tubercle bacillus, which it closely resembles in several particulars. The bacillus, however, is frequently protected by albuminous matter or buried in the dirt of stables, water troughs, harnesses and other objects. While the naked germs of glanders are readily destroyed, they are frequently hard to get at; penetration and cleanliness are, therefore, imperative.

The prevention of glanders in man depends primarily upon the suppression of the disease in horses.

**THE MALLEIN TEST.** Mallein is a product of the glanders bacillus corresponding to tuberculin. The injection of mallein into glanderous animals causes a definite rise in temperature and a local swelling about the site of injection, whereas the injection of mallein into normal animals produces no local reaction and very slight if any rise in temperature. The injection of mallein into the subcutaneous tissues (subcutaneous mallein test) has ceased to be used as a practical method for the field diagnosis of glanders, having been supplanted by the ophthalmic and intradermo-palpebral tests. With the mallein test, latent and occult cases of glanders can be diagnosed, but the test must be made and interpreted by an experienced veterinarian else the results may be unreliable.

**Prevention.** When glanders is discovered or suspected among horses in a stable, the horses in the infected stable should be tested. All animals with glanders should be destroyed without further consideration. After these animals have been killed and properly disposed of, the stable should be thoroughly cleansed and disinfected. All other horses which have in any way been associated with the infected animals should be carefully watched and tested again after three weeks, and, should there be no indication of the disease in the second test, the stable may be considered free from the infection; otherwise the infected animals should be destroyed and the tests repeated every three weeks until the disease has been eliminated.

The eradication of glanders from a stable often means considerable loss and sometimes a sacrifice of valuable animals, but it is only through vigorous measures that the disease may be controlled. In the disinfection and cleansing, special attention should be paid to the stalls, harnesses, water troughs, bits, food containers, curry combs, sponges, and other objects exposed to the infection, which is eliminated mostly in the secretions from the mouth and nose. The common drinking trough for horses spreads the infection. The bacillus of glanders is very susceptible to bleaching powder, and it, therefore, is a cheap and reliable germicide for this purpose.

The personal prophylaxis of glanders in man depends upon the education and care of those who have to handle horses. In working with horses known to be infected, rubber gloves, disinfection, and other methods of protection should be employed. Special care should be taken to prevent the spread of the disease through the discharges or by infected fomites from human cases. Fatal accidents have occurred in laboratories in research workers handling pure cultures of *M. mallei*.

## FOOT AND MOUTH DISEASE

(*Aphthous fever, epizootic catarrh, eczema contagiosa*)

Foot and mouth disease is an acute and highly communicable disease, generally confined to cloven-footed animals, and characterized by an eruption of vesicles on the mucous membrane of the mouth and on the skin between the toes and above the hoofs; sometimes on the udder and other parts of the body. The vesicles rupture, leaving superficial erosions which sometimes develop into ulcers. Other symptoms are salivation, tenderness of the affected parts, loss of appetite, lameness, emaciation, and diminution in the quantity of milk secreted. The period of incubation ranges from 18 hours to three weeks. It is usually short, about three to six days.

Foot and mouth disease is primarily a disease of cattle and rarely of man. It also affects hogs, sheep, goats, deer, buffalo, American bison, the camel, chamois, llama, giraffe, and antelope, and even dogs and cats are said occasionally to become infected. Horses and fowl are not susceptible to the infection.

**Causative Virus.** Loeffler and Frosch, in 1898, showed that the virus will pass the finest porcelain filters. This was the first "ultramicroscopic" virus of animals discovered. The first filtrable virus was discovered by Iwanowski in 1892 as the cause of the mosaic disease of tobacco. In 1898, Beijerinck independently arrived at similar conclusions. In the same year, Loeffler and Frosch published their epoch-making studies on the etiology of foot and mouth disease. Their work has been confirmed and extended by many investigators. The virus is recovered and identified by inoculating suspected material intradermally into the plantar pads of guinea pigs. In 24 to 48 hours a primary vesicle develops, and 24 to 48 hours later secondary vesicles appear on the uninoculated pads (Richter, 1938). The virus can be grown in tissue culture. Complement-fixing and virus-neutralizing antibodies can be demonstrated. Three types of aphthous fever virus have been differentiated by cross immunization tests. These types are designated as "A" and "O" (Vallée) and "C" (Waldman). The observations of Trautwein and Reppin (1932), and Daubney (1934) cast doubt on the fixity of these three types. Variant and intermediate types have been observed. Daubney regards the bovine virus as a labile organism subject to spontaneous phase variations. Active immunization using a formalin killed virus vaccine has recently been employed in Denmark, Germany, Mexico, and other countries.

The original experiments of Loeffler and Frosch, as well as experiments which have been made in Denmark and Germany, indicate that the virus of foot and mouth disease is destroyed comparatively readily by heat. Milk pasteurized at a temperature of 60° C for 20 minutes is safe. It is resistant to many of the germicidal chemicals but is destroyed within a few minutes by a 2 per cent solution of sodium hydroxide (lye) (U. S. Agri. Dept., 1928). Field evidence indicates that the virus may remain alive for months on infected premises.

**Transmission.** The virus is contained in the serum of the vesicles; in the saliva, tears, milk, and various other secretions and excretions; also in the blood until the eruption comes out, when it disappears. Some animals after recovery may be carriers for a considerable period of time.

Animals may be infected directly, as by licking; in calves by sucking; or indirectly by fomites such as infected manure, hay, utensils, drinking troughs, railway cars,



animal markets, barnyards, and pastures. The disease is spread largely through persons who care for, examine, milk, or otherwise handle, diseased animals. Veterinary inspectors must take unusual precautions not to spread the infection in their efforts to control it.

Although relatively resistant, man may occasionally be infected through the ingestion of raw milk, buttermilk, butter, cheese, and whey from animals suffering with foot and mouth disease. It may also, though more rarely, be transmitted directly from the salivary secretions or other infected material which gains entrance through the mucous membrane of the mouth. It is doubtful whether the disease can be transmitted to man by cutaneous or subcutaneous inoculations, though it is probable that the infection may be communicated if the virus enters the blood directly through wounds of any kind. Children may be infected by drinking unboiled milk during the time in which the disease is prevalent in the neighborhood; while persons in charge of diseased animals may become infected through contact with the affected parts or by milking, slaughtering, or caring for the animals. The disease is usually mild in man; death practically never results, except in weakened children, and then from secondary complications.

The clinical manifestations of the infection in man are analogous to those seen in animals (Clough, 1915). There are a considerable number of cases described in medical literature (Arkwright, 1928). In relatively few has the diagnosis been verified by animal inoculation or by demonstrating a rise in serum antibody titer.

**Prevalence and Control.** The disease prevails in European countries, especially Russia; also South America, Asia, and Africa, and occasions great economic loss. The mortality is low; the serious losses depend chiefly upon the diminution of the milk secretion and the loss of flesh in the affected animals as well as the disturbances of quarantine. It occurs as widespread epizootics, especially in the warm season.

Foot and mouth disease has appeared in epidemic form in the United States on 10 different occasions: 1870, the eastern states; 1880 and 1884, Massachusetts; 1902, New England; 1908, Michigan; 1914, Chicago; 1924, California; 1925, Texas; 1929, California; and 1932-1933, California. Each of these outbreaks was suppressed through the application of well-known preventive measures, such as isolation, destruction and burial of the affected herds, disinfection, restriction of the movements of cattle, and a systematic inspection of all farms in the infected area to detect cases of the disease. It pays in the end to use prompt and aggressive measures. Even these measures may be inadequate to control the disease under some conditions as has been illustrated by the recent experience in Mexico (Arocha, 1947; Murnane, 1950).

The efforts of the livestock sanitary authorities were successful in keeping foot and mouth disease out of the North American continent from 1933 to 1946. In May of the latter year, a shipment of zebu bulls from Brazil were landed on Sacrificios Island adjacent to Veracruz, Mexico. The animals appeared to be free from foot and mouth disease and after four months' observation were transferred to a ranch in the state of Veracruz not far from the port. Foot and mouth disease appeared among the cattle on this ranch in October. By January, 1947, it had spread widely among the livestock of eight adjoining states of south central Mexico—an area approximately 150 miles from north to south and 300 miles from west to east.

To cope with this threatening situation the Mexican Ministry of Agriculture and the United States Department of Agriculture set up a joint commission and mobilized their scientific, technical, and financial resources. As rapidly as possible, a campaign was organized to stop the spread of the disease by means of the conventional measures of quarantine and slaughter. By the end of April, 1947, about 93,000 animals had been sent to slaughter or slaughtered on the premises. About one half of these were cattle, the remainder being sheep, swine, and goats. In spite of these efforts, by July the disease had spread to eight more states and the quarantine zone extended across the entire central portion of Mexico. The slaughter of animals was proceeding at the rate of 28,000 cattle and 30,000 smaller animals per week. Millions of dollars were paid out to owners in indemnities. By December of 1947, it was realized that to continue the slaughter campaign to its conclusion would require the destruction of most of the animals in the area, estimated as 5,000,000 cattle and an equivalent number of small animals. Mexico could not stand the economic shock of this wholesale destruction plus the disruptions brought about by the quarantine. Even though paid for the destroyed cattle, angry Mexican farmers murdered 23 of the men working in control parties. The program was modified to provide regrouping and concentration of field forces along the north and south quarantine lines; slaughter and burial of infected and exposed animals was limited to a zone a few miles wide along the north and south of these defense lines. Within the infected area it was planned to build up an immune animal population by means of vaccination. A laboratory was set up for the production and testing of vaccines. Eight strains of virus from Mexico were found to be variants of Type A. On the basis of previous work, it was expected that vaccination would afford protection to the inoculated animal for approximately six months. Thus, it was necessary to plan revaccination of herds twice yearly. Later it was found, however, that protection against the disease could not be expected beyond four months from the time of vaccination, so that it became necessary for all susceptible animals in the quarantine zone to be vaccinated at least three times in one year. By the end of November 1949, more than 37,000,000 cattle, sheep, swine, and goats had been vaccinated. Forty outbreaks of Type A virus were discovered during the year, 37 of which appeared prior to June 30th. The remaining three and an isolated case of Type O were exterminated during the last six months. In 1950, it appeared that the situation was under control although it is uncertain as to whether complete eradication had been effected.

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## TETANUS

(Lockjaw)

Compared with the major plagues of man, lockjaw has always been a rare disease. It is on account of the characteristic and fatal spasms that it early attracted attention. The spasms are tonic in nature, with acute and painful exacerbations. They usually begin in the muscles of the jaw and neck and in severe cases spread to the voluntary muscles of the body and the extremities, producing opisthotonos.

Tetanus usually occurs sporadically; formerly epidemics in hospitals (especially lying-in hospitals) and in wars were rather common. The conditions of trench warfare in World War I favored wound complications, and included a frightful amount of tetanus until antitoxin was used as a routine prophylactic in all wounded. Before the days of asepsis the infection was often spread through surgical instruments, fingers, bandages, etc.

**Historical Note.** Carle and Rattone, in 1884, first clearly demonstrated the infectious nature of tetanus by inoculating rabbits subcutaneously with pus from a human case of the disease. In the same year, Nicolaier inoculated mice and rabbits subcutaneously with garden earth and saw the tetanus bacillus at the site of injection. In 1889, Kitasato for the first time grew the organism in pure culture, and by successful inoculation experiments proved that this bacillus was the cause of tetanus. Kitasato further showed that the tetanus bacillus is not found in the heart's blood of mice dead of tetanus and, therefore, concluded that we are dealing with an intoxication, and not a bacteremia. We now regard tetanus as a type of the true toxemias; that is, the bacilli remain localized in the wound, and the soluble toxin does the damage. This pioneer work of Kitasato's was of great importance, and led to the epoch-making discovery of Von Behring and Kitasato in the following year (1890) upon tetanus and diphtheria toxins and antitoxins, laying the foundation of serum therapy.

**Etiology.** Tetanus is usually the result of the contamination of a wound by material containing the spores of the tetanus bacillus (*Clostridium tetani*) and the subsequent development locally of anaerobic and other conditions favorable to germination and toxin production. All wounds are not equally liable to this complication. Punctured, lacerated and contused wounds are much more susceptible to tetanus than clean-cut or open wounds. The size of the wound is of much less consequence than its character and content. Fatal tetanus may develop from trivial wounds, such as pin scratches, small splinters, insect bites, vaccinations, etc. Necrotic tissue, foreign bodies, pus infections, and other irritants favor the development of tetanus.

Concomitant infection of a wound with other organisms, particularly of the gas gangrene group (*C. septicum*, *C. perfringens*, etc.) apparently may promote germination of *C. tetani* and toxin formation (Weinberg and Sequin, 1917). Unlike the gas gangrene bacilli, however, *C. tetani* is not invasive. It remains localized in the

wounded area. Frequently, this area is quite small even in fatal cases. Fildes (1929) has emphasized the effect of small amounts of calcium salts in lowering the oxidation-reduction potential of tissue to a level which will permit the germination of tetanus spores.

Tetanus bacilli are frequently present in the wounds of patients who do not develop tetanus. For example, Tulloch (1919) recovered *C. tetani* from 19 of 100 wounds in which there was no evidence of tetanus at the time or at a later period. On the other hand, tetanus sometimes occurs where no wound can be found. This is the so-called "idiopathic tetanus."

Tetanus spores have occasionally been found in the lymph glands, liver and other parts of the body, upsetting our previous view that they are always strictly confined to the site of the wound. The spores may remain latent or dormant in scar tissue or the sequestrum of bone and may be released and start an attack weeks or months afterwards, thus giving a plausible explanation of some cases of idiopathic tetanus.

*Tetanus neonatorum*, or tetanus of the newborn, is still a common and fatal infection in some countries. Before the days of asepsis the infection was permitted to enter through the umbilical wound. In certain of the West Indian islands more than one half of the mortality among the Negro infants has been due to this cause.

The placenta is permeable to tetanus antitoxin. Ten Broeck and Bauer (1923) found that when tetanus antitoxin is present in the mother's blood, it is also present in the cord blood of the newborn infant. This is a prophylactic factor of importance. The colostrum under similar circumstances contains this protective antibody.

**Incubation.** The period of incubation in man is usually from 6 to 14 days. The period is directly proportional to the amount of toxin and the severity of the disease. This can readily be demonstrated upon susceptible animals. In a study of 600 serial tests, Rosenau and Anderson found this direct relation between the period of incubation and the severity of symptoms by the subcutaneous injection of varying amounts of toxin into guinea pigs. Thus, guinea pigs receiving fairly large doses showed symptoms on the third day and usually died; when the dose is smaller, the period of incubation is longer, the disease milder, and the chances of recovery greater. In man, with a short period of incubation, six days or less, the disease is almost invariably fatal. With longer periods, the disease is usually milder and recovery may take place without the use of antitoxin. The incubation period is likely to be prolonged when tetanus develops following a prophylactic dose of antitoxin.

**Occurrence.** The spores are not affected by gastric digestion, and in the intestines of certain animals find ideal anaerobic conditions, food supply and temperature for growth and development. Here they multiply and pass in the dejecta to pollute the soil. The soil, therefore, in all regions inhabited by domestic animals is more or less contaminated with tetanus. The bacilli, however, do not multiply in the soil. While the soil acts only as a vehicle, it is the immediate source of most cases of tetanus in man. The presence of tetanus spores in soil, street dust, fresh vegetables and on clothing and the skin may be traced to fecal contamination.

**IN MAN.** Tetanus spores are present to a variable extent in the intestines of man; claims of their occasional occurrence have long been on record. Those who work in contact with manure are most likely to have them. From 5 to 20 per cent of hostlers and dairymen are "tetanus carriers." Ten Broeck and Bauer (1922) demonstrated tetanus bacilli in 34.7 per cent of the stools of 78 persons in Peking.



These investigators also proved that tetanus bacilli grow and multiply in the intestinal tract of man, because several millions of tetanus spores were found in a single stool of a man kept on a practically sterile diet for a month.

**IN ANIMALS.** The normal habitat of tetanus is in the intestinal tract of animals. The main reservoir of tetanus is probably the digestive tube of herbivora, although the spores may be found in a great variety of animals (Noble, 1915). Park found tetanus bacilli in the intestines of about 15 per cent of horses and calves living in the vicinity of New York City.

**IN THE SOIL.** Tetanus spores are frequently found in manure, cultivated or garden soil. Dubovsky and Meyer (1922) even found the spores in virgin forest soil. They may be blown or carried great distances.

Tetanus spores are not equally numerous in all localities. The infection is much more prevalent in warm than in cold countries. It is especially severe in the tropics, yet Iceland at one time suffered severely from tetanus neonatorum. In the United States, tetanus occurs especially in the Atlantic States, and in some parts of Long Island, New Jersey, and the Hudson Valley, which have become noticeable for the number of cases of tetanus complicating small wounds. The soil of the western states is relatively free from this anaerobe. The soil of Flanders and France has through long cultivation become saturated with the spores of tetanus and other anaerobes. One grain of it from the trenches injected into a laboratory animal invariably produced tetanus. Tetanus spores are widely disseminated in India.

**MISCELLANEOUS.** On account of the great resistance of the spores, they are blown about in dust and are spread everywhere by dirt and manure. Tetanus has been found in hay dust, on horses' hair, in the dust of houses, barracks, and hospitals, in the mortar of old masonry, in street dust, on food, in gelatin, on the skin, and in the greatest variety of places.

One of the agencies in the distribution of tetanus spores over limited areas is undoubtedly the common housefly. The poisoned arrowheads of certain savages in the New Hebrides contain tetanus spores obtained by smearing the arrowheads with dirt from crab holes in the swamps (Le Dantic).

Tetanus spores or toxin may contaminate bacterial vaccines, antitoxic sera, vaccine virus, and other biologic products used in human therapy.

A test for tetanus spores is now required by the United States law of July 1, 1902, for all sera and vaccines sold in interstate traffic. As a further precaution against this complication horses undergoing treatment for the production of immune sera are given prophylactic doses of tetanus antitoxin from time to time.

It is, of course, not the rust on a nail that is dangerous, so far as tetanus is concerned, but the spore-bearing dirt it carries into the deep, contused wound that causes the trouble. Gelatin may contain tetanus spores, and the subcutaneous injection of imperfectly sterilized gelatin as a hemostatic has sometimes resulted in accidents.

**Resistance of Organism.** The tetanus *bacillus* is readily destroyed by the ordinary agencies that kill vegetative bacteria. It is killed almost at once in contact with the free oxygen of the air. On the other hand, few, if any, forms of life have a greater resistance than the tetanus *spore*.

The experimental results are sufficiently varied and conflicting to suggest that races of tetanus bacilli exist, the spores of which vary widely in their resistance to

moist heat at 100° C. Theobald Smith (1908) found that under certain conditions of sterilization some tetanus spores survive a single boiling or streaming steam regularly for 20 minutes, usually for 40 minutes, and occasionally for 60 minutes; in one case 70 minutes' exposure did not destroy the spores. He also showed the possibility of tetanus spores surviving in culture fluids sterilized by discontinuous boiling or steaming in routine laboratory work for fully 20 minutes on three successive days.

In general, dry spores are more resistant than moist spores; and young spores are often harder to kill than old spores.

Tetanus spores resist the action of 5 per cent carbolic acid for 10 hours, but are killed in 15 hours. A 5 per cent solution of carbolic acid, however, to which 0.5 per cent of hydrochloric acid has been added, destroys them in two hours. Bichloride of mercury 1:1,000 kills the spores in three hours, and in 30 minutes when 0.5 per cent of hydrochloric acid is added to the solution. According to Park, silver nitrate solution destroys the spores of average resistance in one minute in 1 per cent solution, and in about five minutes in a 1:1,000 solution. *Tetanus spores are destroyed with certainty when exposed to dry heat at or above 160° C for one hour, or to steam at 120° C for 20 minutes. Entire confidence may be placed upon either of these two methods, provided there is direct exposure.*

Direct sunlight does not kill the spores, but seems to diminish their virulence. Under certain circumstances they may live a long time; Henrijean reports that, by means of a splinter of wood which once caused tetanus, he was able after 11 years again to cause the disease by inoculating an animal with the infective material.

**Frequency of Disease.** Since reporting of tetanus is incomplete, mortality records furnish the best indication of its prevalence. Changes made in 1938 in the assignment of priority of causes of death render mortality statistics subsequent to that year deficient for this disease. Prior to that time, deaths from tetanus arising from injuries were included, but deaths from tetanus following surgical operations, abortions or childbirth were not counted as such. With this in mind, Table 9-1, based on the United States Census Bureau Mortality Reports for the years 1934-1938 inclusive, will give some idea of the distribution of mortality by age, sex, and

Table 9-1. Tetanus mortality in the United States, 1934-1938 (exclusive of deaths from tetanus secondary to surgical operations, pregnancy, childbirth and the puerperium)

Age Group	Number of Deaths in 5-year Period				Average Mortality Rate per 100,000 Estimated Population Per Year			
	White		Nonwhite		White		Nonwhite	
	Males	Females	Males	Females	Males	Females	Males	Females
Under 1	252	167	237	144	5.36	3.69	39.17	23.48
1-4	185	112	53	27	.94	.59	2.00	1.01
5-14	900	340	247	93	1.73	.67	3.61	1.35
15-24	342	85	107	51	.76	.16	1.74	.74
25-34	166	76	106	34	.37	.16	2.07	.60
35-54	399	177	164	91	.53	.25	2.14	1.20
55 and over	397	176	77	22	.95	.43	2.41	.77
All ages	2,641	1,133	991	462	.91	.40	3.07	1.40



race at that time. This table shows that males had higher mortality than females at all ages, averaging a little over twice as high; that mortality was considerably higher in the nonwhite population; and that deaths under one year of age (presumably consisting almost entirely of tetanus neonatorum due to umbilical cord infection) are the greatest problem. The great difference from mortality from tetanus in infancy between the white and the colored populations is especially noteworthy and presumably due to unhygienic practices in the care of the cord in the latter group. Exclusive of infancy, the period of later childhood presents the highest risk of mortality, although age differences are not marked.

**Prophylaxis.** Following Ramon's discovery of a method of detoxifying diphtheria toxin by tormalin, Descombey (1924) produced a tetanus toxoid. Ramon and Zoeller (1933) suggested the employment of this agent in active immunization of man. It was pointed out by d'Antona and Valensin (1937) that active immunization of guinea pigs afforded a more effective protection against injected toxin than did passive immunization.

Since 1933, toxoid has been employed on an ever increasing scale, World War II providing a large impetus to its use. Active immunization has been administered to exposed groups and in pediatric practice, followed by stimulating injections at various intervals and by "emergency booster" doses after injury. A number of workers have investigated blood antitoxin titers after active immunization. Bigler (1951) has reported detectable amounts of antitoxin in the blood of children tested up to 10 years after administration of two or three injections of toxoid. A sharp rise in titer occurred within one week after a booster dose.

The U. S. Armed Forces have actively immunized all personnel with tetanus toxoid since 1941. Until 1949, the Army and Air Forces employed fluid toxoid, while the Navy used alum-precipitated toxoid; now all of the services use the latter.

The routine procedure in the Army during World War II consisted of giving three subcutaneous injections of 1 ml. of fluid toxoid at intervals of three weeks upon enlistment, with a "routine" stimulating dose of 1 ml. a year later. Until 1944, additional doses were frequently administered to troops likely to enter active combat; this was probably unnecessary. An "emergency" stimulating dose was given to all previously immunized persons who sustained wounds, burns or injuries thought to carry a hazard of tetanus. A record of the dates of basic immunization and the routine stimulating injection was made on each soldier's metal identification tag; tetanus antitoxin was given to wounded men only if they did not possess such a record. The procedure with alum-precipitated toxoid was the same except that an initial series of only two doses of 0.5 ml. one or two months apart was required.

World War II provided a test of active prophylaxis just as World War I had demonstrated the value of prophylactic antitoxin. Long and Sartwell (1947) report that 12 cases of tetanus occurred among Army and Air Forces personnel in World War II, five of which were fatal. Of these 12 cases, six had received no active immunization (these men had not been in the service long enough to receive toxoid); two had received the basic series but no emergency stimulating dose; and the remaining four had been fully immunized. Only one of the 12 cases resulted from wounding in battle (there were about 600,000 such wounds). Mortality from tetanus in the Army amounted to 0.02 deaths per 100,000 troops per year; the United States mortality rate for white males, aged 15 to 34, in the period 1934 to 1938, was

0.52 per 100,000, a figure more than 20 times as high. The contrast is especially remarkable in the light of the fact that there is a vastly greater hazard in military services of injuries which might lead to tetanus.

The Navy had an equally favorable experience, as reported by Hall (1948). During World War II there were four cases of tetanus with two deaths, only one being in a fully immunized person.

Tetanus prophylaxis in the British Armies differed somewhat from that described above, especially in that actively immunized men who sustained injuries were given antitoxin instead of toxoid. Boyd (1946) states that during the war period there were 35 cases of tetanus due to battle injuries among British and Colonial troops, of whom 16 had not been actively immunized. Eighteen additional cases occurred following nonbattle injuries.

From accounts of the amount of tetanus in wounded German and Japanese troops, as well as civilians wounded in military operations, there can be no doubt that this disease would have taken a high toll of lives had our forces not been protected.

While all reports have indicated the efficacy of toxoid, passive protection with antitoxin is also effective. The use of toxoid offers two advantages: first, it provides at least some protection, as pointed out above, against the risk of tetanus following minor injuries which do not require or receive medical attention; and second, it eliminates the need for administration of antitoxin, an agent which contains horse serum and, therefore, carries a definite risk of serum sickness or anaphylactic reactions, particularly on repeated use. While some immediate reactions of sensitivity to toxoid were reported by Long (1943) and attributed to the type of peptones contained in the culture media, such reactions became extremely rare after the use of toxoid containing these peptones was discontinued. Thus, toxoid can be administered repeatedly with practically no hazard of serious reactions.

The question of how widely to employ routine active immunization is receiving considerable attention. Press (1948) has discussed the pros and cons. His summary of the findings of eight investigators who studied the types of injuries preceding onset of tetanus is of interest. These eight series ranged in size from 25 to 352 cases, and the percentages of cases giving no history of injury varied from 10 to 46 per cent. From 20 to 53 per cent of cases in the different series gave a history of only trivial injuries; many of the latter were so trivial that medical attention would not have been sought for them (examples are infected insect bites, and superficial cuts and scratches). The high relative frequency of cases with no known injury or minor injury is undoubtedly related to the practice of administering antitoxin for more serious wounds, thus reducing the number complicated by tetanus, as well as to improvements in surgical technics; yet it appears that there is little hope of much further reduction in the incidence of tetanus without resorting to active immunization. Active immunization will prevent these cases resulting from trivial wounds only if, as seems probable, it is unnecessary to give toxoid at the time of the injury to the basically immunized person.

Pratt (1945), in a study of 56 cases in children, included in the summary by Press, pointed out that 11 cases (20 per cent) had had injuries that usually would be treated by a physician, and that many physicians would feel warranted the use of antitoxin or toxoid. Another 20 per cent had injuries so trivial that medical



attention would seldom be sought; if treated by a physician tetanus antitoxin would probably not be employed, although a booster shot of toxoid might be given if the patient had previously been actively immunized. The third group (34 cases, or 60 per cent) represented types of injury in which it is most improbable that either antitoxin or booster injections of toxoid might have been used. Of these 34 cases, 16 (29 per cent of the entire series) gave no history of injury; seven followed vaccinations; five followed minor cuts on the hand; five were due to umbilical cord infection and one resulted from a boil on the leg.

One obstacle to the full utilization of the advantages of toxoid over antitoxin is the fact that the physician treating an injured patient often cannot determine whether his patient has been actively immunized. This disadvantage does not exist in military medical practice; every soldier is routinely immunized shortly after enlistment and, in addition, his identification tag, which is worn at all times, and his immunization register both carry entries indicating the dates of immunization. Under civilian conditions, a record of immunizations is frequently not available and an injured person often cannot give a reliable statement to the doctor on this point. Thus, it becomes necessary to give antitoxin with the attendant hazard of reactions despite the fact that the patient has been actively immunized. Tattooing patients with a symbol to indicate that they have received full immunization might be suggested but it is doubtful whether this would be acceptable. Some means should be found in these days of extensive travel, accident hazard, and possible civil participation in the fruits of war to ensure the availability of information concerning each person's blood group and immunization status.

**LOCAL TREATMENT OF WOUNDS.** Surgical treatment of the wound as soon as possible is the first important measure in the prevention of tetanus. Wounds, however insignificant, should be thoroughly cleansed. Punctured or lacerated wounds, in which there is special danger of tetanus, should be freely opened, and every particle of foreign matter carefully removed. Promptness in cleansing the wound surgically is almost as important as thoroughness. Gunshot wounds and wounds containing garden earth, street dust, or other material liable to contain tetanus spores should receive special consideration. All necrotic tissue, or tissue likely to die, must be removed. The experience of World War I demonstrated that thorough excision of the wound (*débridement*) is good practice. Ordinary germicides are useless. Iodine within three to four hours after injury may be effective for organisms still on the surface. The surgeon's knife is the best antiseptic. The division of the umbilical cord and the treatment of the navel in the newborn must be done under the strictest asepsis. Wounds in which there is suspicion of tetanus should be kept open and freely drained and otherwise treated so as to discourage anaerobic conditions.

**PASSIVE IMMUNIZATION.** Tetanus antitoxin is a specific and trustworthy preventive. The great experience of World War I adds confirmation to the protective power of this specific serum. Its use, however, must be understood to achieve satisfactory results. The antitoxin should be administered before the advent of symptoms, for after the tetanus toxin has combined with the motor nerve cells in the central nervous system, it is displaced or neutralized with difficulty, if at all. As with other antitoxins, a small amount given early is better than great quantities later. It is, however, practical to give antitoxin to the point of saturation in the disease. This is

done with the knowledge that it will fix and neutralize the free toxin and thus prevent further damage, and with the hope that it will dissociate some of the poison combined with the central nervous tissue. After symptoms have commenced, large doses should be given intravenously and subcutaneously as well as into the spinal canal and into the nerves leading from the wound.

The standard prophylactic dose of tetanus antitoxin has been considered to be 1,500 U. S. A. units (3,000 International units). Certain investigators believe this to be too little and suggest a dosage of 10,000 to 20,000 units, the larger amount being reserved for severe injuries or cases where seroprophylaxis is delayed. In cases where a tetanus hazard is considered to be still present, as in wounds containing necrotic tissue or a foreign body, or after secondary operations, administration of a further dose after one or two weeks may be indicated, care being taken to avoid anaphylactic reactions from sensitivity developing after the first dose. Since antitoxin contains horse serum, patients must always be tested for sensitivity prior to the injection and those who are sensitive cautiously desensitized. Active immunization may be initiated in patients who have been passively immunized, the findings of Cooke and Jones (1943) suggest that it is best to wait two to four weeks or longer after giving prophylactic antitoxin before beginning the series of toxoid injections, since the development of active immunity appears to be inhibited when there is considerable antitoxin in the blood resulting from passive immunization.

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## RABIES

*(Hydrophobia)*

Rabies is an acute, specific, rapidly fatal paralytic infection communicated from a rabid animal to a susceptible animal, through a wound usually produced by biting. Man always contracts the disease from some lower animal, commonly the dog. Rabies belongs to the group of virus diseases. The virus is harmless when ingested provided the mucosa is intact. *Rabies is a wound infection.*

The disease is remarkable in several particulars, especially the period of incubation, which is more variable and more prolonged than that of any other acute infection, and its high mortality, which is practically 100 per cent. Spontaneous recovery from rabies naturally acquired is rare if it occurs at all.

**Prevalence.** Rabies has been known since the dawn of civilization. Stone murals from ancient Rome, Greece, and Egypt depict mad dogs; Greek mythology has reference to the disease. Gradually, its world-wide distribution was realized. A few geographically isolated areas remained free—Australia, Hawaii, and some of the smaller islands.

In Europe, during the eighteenth and nineteenth centuries, there were widespread epizootics of canine rabies suppressed in local areas from time to time by rigid dog control measures. In 1815, rabies appeared for the first time in Denmark and Norway, and in 1824 in Sweden. It was quickly eliminated from these countries and they have remained free from the disease to the present time. In England, the incidence of rabies in man and animals during the nineteenth century fluctuated with periods of enforcement and relaxation of dog control measures. It was completely eradicated by 1903 and quarantine regulations to prevent importation have been rigidly enforced since that time. Although reintroduced in 1918 by a dog carried over from the continent by plane, it was again free by 1921 and has remained so.

The earliest account of rabies in North America was in 1768 when the disease appeared in the vicinity of Boston. From this focus it gradually spread with the settlement of the country. By 1900 it was enzootic over most of the United States. Several major outbreaks of rabies in wild animals have been recorded. Notable are the epizootics in skunks (Kansas, 1875; Arizona, 1907-1910), in coyotes (Nevada, Oregon, California, 1915-1916); in foxes (Massachusetts, 1812; Alaska, 1915). Between 1937 and 1944 fox rabies was reported in 20 states (Johnson, 1945a). Whenever wild canine species, such as the fox and the coyote, are allowed to become abundant in an area there is a constant threat that rabies will become prevalent.

The preponderance of infections in animals with this virus in the United States is, of course, in dogs. In this species it maintains its transmission from year to year and from place to place in most of the states of this country with periods of regional increase and decrease. In 1945, 14 states reported to the Federal Department of Agriculture that they had had no rabies in either animals or human beings; this group included the New England and eight western states. Although the number of human beings who die of rabies each year is relatively small (25 to 50 in the U. S. Registration Area), approximately 30,000 persons receive rabies vaccine treatment each year.

**Seasonal Distribution.** There is an old superstition that rabies is prevalent

Table 9-2. Number of cases of rabies in man and animals reported in the United States, 1938-1949 \*

Year	Dogs	Cattle	Horses	Sheep	Swine	Cats	Goats	Miscellaneous	Man	Total
1938	8,452	413	32	164	42	207	11	44	47	9,412
1939	7,386	358	36	17	38	269	10	172	30	8,314
1940	6,194	326	25	53	71	260	4	277	28	7,238
1941	6,648	418	39	68	159	294	9	212	30	7,877
1942	6,332	288	15	48	32	250	12	160	28	7,165
1943	8,515	349	35	45	60	316	19	310	41	9,690
1944	9,067	561	32	40	43	419	14	311	53	10,540
1945	8,505	487	46	11	30	466	10	373	35	9,963
1946	8,384	962	44	15	22	455	12	956	22	10,872
1947	6,949	766	40	15	20	393	9	728	26	8,946
1948	6,610	599	34	14	36	378	5	819	13	8,508
1949	5,237	639	24	22	54	413	6	1,192	10	7,597

\* Figures from the Bureau of Animal Industry, U. S. Department of Agriculture. (Miscellaneous other animals include mostly wild species such as foxes, wolves, coyotes, skunks, etc.)

during the hot summer months. However, it has been found from repeated analyses that the incidence is fairly uniform throughout the year, with some seasonal increase in the late winter or early spring. This may well be due to the fact that the stray dog, wolf, and fox range more widely during these months in search of food and mate. Epizootics of rabies may occur at any time of the year.

**The Disease in Dogs.** A normal dog that is bitten by a rabid animal may develop rabies in as short a time as 10 days, or it may show no symptoms until several months later. In most instances, rabies will develop from 21 to 60 days after exposure. The virus is not present in the saliva until the early symptoms of the disease appear.

Rabies in dogs is usually classified as furious or dumb, depending upon the symptoms shown by the animal.

**FURIOUS RABIES.** During the early stage of the disease, a dog may appear quite normal and be even more affectionate than usual. Despite its friendly actions the dog will be easily irritated, especially if restrained in any way. If picked up, it will immediately try to break away and, if not promptly freed, will bite savagely. This is usually the way children are bitten, because they will pick up a friendly looking dog and try to hold it when the animal attempts to get away. Restlessness and excitement are other early symptoms that will be shown by the dog. The dog will seldom be still for more than a moment and will snap at flies and chase chickens, cats, and domestic animals. It also will have a tendency to eat sticks, straw, earth, and other indigestible material. After a period of one to three days, the dog may become extremely vicious and will bite any living thing that gets in its way, including its master. The eyes will be glazed and constantly wide open. Often there will be a peculiar howl-like bark. During this stage, the dog will usually wander away from home, roam the countryside, and attack any person or animal it sees. Within a few days paralysis will develop, first shown by a wobbly or staggering gait. Paralysis will then extend until the animal cannot get up. Dogs with this type of the disease usually live several days and may live as long as 11 days after developing symptoms.

**DUMB RABIES.** In this type of the disease, the early symptoms consist of sleepi-



ness and melancholia; the dog will try to hide or get away by itself. These symptoms are soon followed by paralysis of the jaw, throat, voice and leg muscles. There will be no irritability or tendency to bite, but persons may be exposed to rabies by trying to look at the animal's throat or while giving medicine. Animals so affected seldom live more than three days after developing symptoms.

In most cases, rabid dogs show symptoms of both types of the disease, that is, a period of restlessness, excitement, and irritability, during which they appear friendly and unusually alert, followed by rapid progression to paralysis of the dumb rabies type. Some animals affected with rabies die suddenly without showing any symptoms of illness. In other instances, the first symptom is a convulsive seizure during which the animal may die.

It is to be noted that dogs and other animals suffering from rabies are without fear. Rabid wild animals, such as foxes and skunks, will fearlessly invade farm premises and attack persons, dogs, and domestic animals in daytime. The disease makes them insensible to pain, and blows or gunshot will not frighten them.

**Conditions of Transmission.** Transmission of the disease depends primarily upon localization and excretion of the virus from the salivary glands. Usually, it appears at about the time of onset of the prodromal symptoms. Several investigators have reported finding the virus occasionally present in the saliva of dogs from 4 to 14 days before the appearance of the disease. It is, therefore, sufficient to watch for 14 days a dog that has bitten a person, and if no symptoms of rabies appear in the dog during that time, there is no danger of conveying the disease and the Pasteur prophylactic treatment is unnecessary. Fourteen days has a factor of safety. Practically, the danger from a bite during the preclinical stage of the disease is slight. While it is possible that dogs in rare instances may develop an abortive type of rabies and recover, it is extremely unlikely that the animal so affected will have the virus in its salivary glands (Johnson, 1943). There is at present no evidence to indicate that the dog can act as a symptomless carrier of rabies.

The development of rabies following exposure to a rabid animal depends upon a number of other factors. The bites of horses and other herbivora are less dangerous than are the bites of wolves, dogs, foxes and other members of the canine species. Of great importance is the nature of the wound. The more the skin and underlying tissues are lacerated the greater the danger of infection. Bites on exposed surfaces are more dangerous than through clothing, since in the latter case the saliva may be wiped off and little or none enter the wound. Long haired dogs and sheep often escape infection for the same reason. This accounts, at least in part, for the differences due to location of the bite. For example, Dobert noted that 12 cases of rabies developed among 118 persons bitten on the head (10 per cent), 24 cases among 1,251 persons bitten on the arms (2 per cent), one out of 564 bitten on the legs (0.2 per cent) and no cases among 72 bitten on the trunk. Occasionally, an individual is infected with rabies by exposure to the licking of the skin by a rabid animal. In these instances, it is assumed that there exists a minute abrasion through which the virus makes contact with nerve endings.

Because of these many variables, it is impossible to estimate accurately the risk of rabies to an individual who is exposed to a rabid animal. Such information as is available comes principally from the time period before prophylactic treatment by vaccination was introduced and before the diagnosis of rabies was confirmed by

laboratory examination. For example, Faber reported that only 36 (6 per cent) of 597 persons bitten by rabid animals developed rabies. Kirshner of Prussia recorded 38 deaths (3 per cent) among 1,453 persons bitten by rabid dogs. Schuder noted only 1,325 deaths (9 per cent) in a group of 14,959 persons bitten by rabid animals. These and other observations coming down from this period, suggest that a great majority of individuals exposed to a rabid animal escape infection even though they are not given prophylactic treatment with vaccine.

**Period of Incubation in Man.** There is still some doubt as to the route by which the virus travels from the injured tissues to the central nervous system. The balance of evidence indicates that the virus travels predominantly by way of the sensory nerves. Ability to infect animals by means of a scratch on the cornea or skin supports this theory. The blood stream and the perineural lymphatics do not appear to play any significant part in the invasion or propagation of the virus. Rabies virus, however, is not strictly neurotropic. Submaxillary glands are the best source of virus aside from the central nervous system. Concentration of the virus in these glands is often as high as that in the brain.

In man, the average incubation period is 42 days. Rabies may develop as early as 10 days after exposure. Incubation periods of over 90 days are relatively rare. In Harald Johnson's experience with 137 cases of human rabies, the longest incubation period was 210 days. The average incubation period for children developing rabies is shorter than for adults. Experimental studies show that the amount of virus introduced and the type of tissue exposed influence the duration of the latent period. Temporary arrest of virus multiplication may occur either at the site of infection or at some place in the nervous system.

**Diagnosis.** The diagnosis of rabies (Johnson and Sellers, 1948) is based on the consideration of as many of the following factors as are available: history of exposure, clinical symptoms and course, termination of illness, microscopic demonstration of Negri bodies in the brain, and inoculation of experimental animals with emulsions of brain tissue. Of these, the first and second are of the utmost importance in consideration of the necessity of arriving at a decision in the shortest possible time. To this end, it should be emphasized that when an animal is suspected of having the disease it should not be killed immediately but, if possible, apprehended and confined under observation of a veterinarian for at least 14 days. Ordinarily, the animal will succumb within five days if it has rabies.

The specimen submitted to the laboratory for the confirmation of diagnosis is the head of the suspected animal. It should reach the laboratory in as fresh condition as possible, using refrigeration if necessary in shipment. The brain should be removed with aseptic precautions. The specific intracytoplasmic inclusion (Negri) bodies when present are readily demonstrated in smears or impressions made from the Ammons horn of the brain, stained with Seller's carbofuchsin, methylene blue, or some other similar method. A positive microscopic diagnosis is sufficient for the diagnosis of rabies. However, only about 90 per cent of the proved rabid dogs have Negri bodies in the brain. The finding depends upon the duration of the disease before the animal is killed or dies of rabies. Therefore, if the microscopic examination of a brain specimen is negative, it is necessary to use animal inoculation in order to establish the diagnosis.

For this purpose, a mouse test developed by Webster and Dawson is in general



use. The advantages of the mouse are: its low cost, making possible the use of several animals for testing one specimen; the relative short incubation period of rabies in the animal; and the consistency of the production of Negri bodies in the brains of mice inoculated cerebrally with rabies virus. It is preferable to use mice between three and six weeks of age. A 10 per cent emulsion of the suspected brain tissue is prepared in normal saline, centrifuged at 2,000 r.p.m. for 5 or 10 minutes and the supernatant fluid used for the test inoculation. A dose of 0.03 ml. is injected intracerebrally by means of a tuberculin syringe, using at least four mice for each specimen. If a specimen is positive, some of the mice usually show symptoms between the sixth and eighth day after inoculation. After the development of symptoms, Negri bodies are usually numerous and can be found throughout the brain. In routine mouse inoculation tests, surviving mice are ordinarily discarded and destroyed on the thirtieth day following cerebral inoculation.

**Prevention.** The prevention of rabies is considered under three heads: (1) treatment of the wound; (2) the Pasteur prophylactic treatment; and (3) the control of the disease in dogs.

The cauterization of the wound and the Pasteur prophylactic treatment are efficient preventive measures for the individual, but they are not the true methods of controlling and preventing the disease. Rabies may be checked, even eliminated, by measures directed toward the dog.

**Local Treatment of the Wound.** CAUTERIZATION WITH NITRIC ACID. Wounds produced by the bite of an animal, in which there is any possibility of rabies, should at once be cauterized with "fuming" or strong nitric acid. The acid is best applied with a glass rod thoroughly to all parts of the wound, care being taken that pockets and recesses do not escape. Punctured wounds should be laid open to allow proper cauterization. Rosenau's experiments indicated the importance also of cauterizing the edges of the skin.

Thorough cauterization with nitric acid reduces the danger of wound complications, and experience demonstrates that wounds promptly and thoroughly cauterized with nitric acid are seldom followed by rabies. Cabot obtained the best results with nitric acid and was able to save the lives of 91 per cent of guinea pigs by cauterization with nitric acid at the end of 24 hours; Poor saved 45 per cent at the end of 22 hours. Experiments under Rosenau's supervision (unpublished) indicate that practically all guinea pigs may be saved by prompt application of nitric acid; that its effectiveness decreases with time, but that it is still partially protective up to 48 hours. Strong germicides, such as carbolic acid, are not reliable; nitrate of silver is valueless; formalin and the actual cautery are not effective. Recently Shaughnessy and Zichis (1943) have compared the effectiveness of nitric acid, 20 per cent green soap solution, and tincture of iodine for the treatment of wounds in infected guinea pigs. They found that the green soap solution was as effective as nitric acid where the treatment was carried out within two hours after exposure. Tincture of iodine was less effective.

**Pasteur Prophylactic Treatment.** This method was announced December 6, 1883, by Pasteur, at the International Congress at Copenhagen, and on February 24, 1884, he laid before the French Academy the details of his experiments and results. The next year Pasteur, with the help of Roux and Chamberland, worked out the details of the method, modifications of which are now in general use.

The principle of the treatment consists in producing an active immunity by means of a modified virus, which is attenuated by drying. The fixed virus contained in the spinal cord of rabbits dead of hydrophobia is emulsified and injected subcutaneously.

The distinction between street and fixed virus is of fundamental importance with reference to immunity.

**STREET VIRUS AND FIXED VIRUS.** *Street virus* refers to the virus as it is found in nature. It was so called by Pasteur because he obtained it from mad dogs brought in from the streets of Paris. When this virus is inoculated subdurally into a rabbit, the disease is reproduced after a variable and often prolonged incubation period, 14 to 21 days or more. If the virus is then conveyed from rabbit to rabbit through a series of transfers, it becomes progressively more virulent for rabbits. The period of incubation is shortened, until finally the rabbits invariably sicken on the sixth or seventh day and die on the ninth or tenth. When the virus has reached this degree of virulence for rabbits, it is said to be *fixed* for the reason that its virulence remains constant. In its passage through rabbits the modification from street virus to fixed virus is gradual. It is important to note that fixed virus, which has attained a high degree of virulence for rabbits, has lost much of its potency for dogs and seems to be avirulent for man when introduced into the subcutaneous tissue.

*Fixed virus* is cited as an example of "mutation" of a pathogenic micro-organism by animal passage. The morphology of the Negri bodies is altered, and according to Levaditi fixed virus has lost the special pansporoblastic cycle of evolution represented by the Negri bodies. Pasteur showed that the virus may be intensified by successive passage through certain animals, as guinea pigs, rabbits, and cats; and weakened by passage through other species, as monkeys, etc.

The subcutaneous tissue is evidently resistant to the fixed virus; indeed, even when street virus is injected subcutaneously into susceptible animals the results are uncertain. Marx tested the fresh fixed virus upon monkeys in large doses with negative results. Levaditi reproduced the disease in a chimpanzee intracerebrally. Many hundreds of thousands of persons have been injected subcutaneously with the fixed virus since 1884, when Pasteur announced his discovery, with satisfactory protection against rabies and without untoward effects. It is suggested, however, that the fixed virus may occasionally be pathogenic for man when injected subcutaneously in view of the paralysis which sometimes complicates the Pasteur prophylactic treatment, but the interpretation of these cases is not settled.

**Preparation of the Virus.** Rabbits are injected under the dura mater with a few drops of an emulsion of fresh fixed virus. Strict aseptic precautions are necessary in order to keep out other infections. The rabbit should begin to show symptoms on the sixth or seventh day, and die on the ninth or tenth. Usually the rabbit is not allowed to die, but is chloroformed in order to avoid terminal infections and unnecessary suffering. The spinal cord is removed and hung in a bottle containing potassium hydroxide, and kept in the dark at a temperature of 22° C. Under these conditions the cord dries, and at the same time the virulence of the virus diminishes until it is no longer infective.

Pasteur was well on the safe side in starting treatment with cord 14 days old;



in fact, the virus dies long before the fourteenth day; five-day cord usually fails to infect, and eight-day cord has lost its power of producing the disease.

About one-half a centimeter of the cord constitutes a dose. This is ground in about 2.5 ml. of sterile salt solution so as to produce a uniform emulsion, and strained through gauze. This suspension is injected into the subcutaneous tissue of the abdominal wall. Pasteur began with cord 14 days old and gradually worked up to cord three days old. The injections were given daily for a period of 18 days (mild treatment) or 21 days (intensive treatment). The dosage is approximate and the scheme of injection somewhat elastic and gradually has undergone modification.

Bacteriologic examinations are made of parts of the spinal cord in order to insure the absence of bacteria, and the rabbit is carefully autopsied as a guarantee that no other disease is present.

**OTHER METHODS.** The classic schema of Pasteur has been modified in various ways to attenuate, inactivate or control the dosage of fixed virus contained in nervous tissue emulsions or extracts. Instead of drying infected rabbit spinal cords, Höyges obtained a similar result through serial dilution of an emulsion of active material and Babes through a 15-minute exposure to temperatures ranging from 80° to 45° C. Harris introduced desiccation from the frozen state. Many investigators have shown that fixed virus inactivated in the presence of phenol retains its capacity to immunize (Semple and others). Vaccines have been developed in which virus is inactivated by formalin (Cumming), ether (Remlinger), chloroform (Kelser), ultraviolet irradiation (Hodes and others), and mustard compounds (Ten Broeck and Herriott).

The development of a mouse test (Habel, 1940) for assaying the potency of rabies vaccine has resulted in improvement in production. Rabies vaccine distributed by commercial biological laboratories in the United States for immunization of man and animals must pass a prescribed test.

*The Semple Method.* The Semple method is fast becoming the method of choice on account of its simplicity and apparent effectiveness.

The material for the prophylactic injections is prepared from the fresh fixed virus in the brain, medulla and spinal cord of rabbits. An 8 per cent suspension of the brain, medulla and cord is made by grinding it up in sterile normal saline containing 1 per cent carbolic acid. This is strained through fine muslin and kept at 37° C for 24 hours. At the end of this period the virus is dead; at least it is not infective when injected into susceptible animals. The material is now diluted with an equal volume of sterile normal saline solution. This final dilution contains 4 per cent of the virus material in 0.5 per cent carbolic acid normal saline solution. The dose is 2.5 ml. injected into the subcutaneous tissues of the abdominal walls once a day for 14 days.

The claim for the Semple method is that the suspension retains its maximum potency and powers of immunization for a period of at least three months. The material injected contains the smallest amount of nerve tissue commensurate with efficient treatment. The dosage is more accurate than with the attenuated cord method, since the cords vary greatly in size. The Semple method is economical and further convenient as the vaccine may be produced in quantity and the whole treatment sent in one shipment. All doses of the vaccine are the same, regardless

of age, sex, severity of the bite or location of the wound. On account of the danger from bites on the face and multiple bites there is a tendency to give more intensive treatment in these cases.

**CARE DURING TREATMENT.** Rigid precautions are not necessary. During treatment the patient may go about his usual business. It is not necessary to stay in bed.

**COMPLICATIONS OF TREATMENT.** The complications are (1) local reactions or (2) paralysis.

*Local Reactions.* Local reactions at the site of the wound are usually trivial. Abscesses do not occur. The local reactions consist of redness and induration. It is not necessarily the last injection, but rather the site of some previous injection that flares up, but soon subsides without further trouble. This occurrence increases with the progress of the treatment; it is most frequent in the second week. As the treatment involves the introduction of foreign proteins into the body, it is probable that these reactions are explained in term of allergy.

*Paralysis.* Paralysis, when it occurs, comes on during or shortly after the treatment. It usually consists of brief weakness of limited groups of muscles affecting the extremities or the face. Sometimes the complication is neuritic and occasionally paraplegic. Exceptionally, the paralysis is of the ascending or Landry's type and ends fatally when it affects the muscles of respiration. It is not easy to differentiate between this complication and true paralytic rabies which may occur during the course of treatment.

Acute encephalitis caused by vaccine is characterized by high fever, delirium, convulsions and coma which may terminate in death. Nonfatal cases ordinarily recover without sequellae. This type of reaction is thought to be due to specific sensitiveness to brain material (Rivers and others, 1933; Morgan, 1947; Kabat and others, 1947). Experimentally, Habel and others (1949) have been able to remove from rabies vaccine by chemical extraction the factor which causes this allergic encephalitis.

Many estimates have been made of the risk of postvaccinal paralysis. The complication occurs following all the different modifications of the Pasteur treatment. Its frequency is best indicated by the reports on antirabies treatments supplied by Pasteur institutes to the Health Section of the League of Nations. Greenwood (1945-1946), summarizing the experience from his own and nine previous reviews of McKendrick, and taking into consideration all forms of treatment, estimated the risk of postvaccinal neuromuscular accident to be 1:5,814. Approximately one in four was fatal—a treatment fatality rate of 0.004 per cent. Experience in the United States is indicated by two recent reports. Sellers (1947) recorded seven cases of vaccine paralysis among approximately 50,000 with a phenol-treated vaccine containing active fixed virus; of these seven cases, five occurred in persons who had been treated with rabies vaccine previously. Pait and Pearson (1949), reviewing the experience of Los Angeles City and County from 1940 to 1946, found that there had been nine cases of severe postvaccinal reactions, including one death, among 5,500 receiving the vaccine, an incidence of 1:600 and a fatality rate of 0.018 per cent. It would be useful to know the risk of neuromuscular accidents associated with the use of each modification of the Pasteur treatment. The data available for this purpose are not sufficiently accurate and detailed to permit valid comparisons.



**IMMUNITY CONFERRED BY PROPHYLACTIC TREATMENT.** The immunity appears about two weeks after the treatment and lasts a varying period of time. In this respect it does not differ from other instances of acquired immunity. In one of Park's cases, it wore off in 14 months, the patient dying of hydrophobia after having been bitten a second time. The Pasteur prophylactic treatment, should, therefore, be repeated in persons bitten a second time. Marie found that dogs remained protected 18 months after treatment.

Immune bodies are demonstrable in the blood 20 days after the last injection. The activity of the virus can be neutralized by mixing it *in vitro* with the blood serum of an immunized animal.

**Contraindications.** There are no known contraindications to the treatment. All ages and conditions should be treated if exposed. Apparently no harm is done pregnant women. The treatment may be continued in patients having colds, fevers and other ailments without noticeable harm.

**TREATMENT FAILURE.** Since the introduction of the vaccine treatment, it has been apparent that the disease could not be prevented if the incubation period were short. For this reason, deaths occurring within two weeks of exposure to the bite of a rabid animal cannot properly be attributed to failure of the vaccine treatment. Indeed, one might take a more conservative view and regard only those cases which develop the disease two or more weeks following the completion of the treatment as failures, since maximum immunity cannot be expected before that time.

The most comprehensive data on deaths following antirabies treatment is that collected and published in a series of reports for the Health Section, League of Nations. In the tenth or last of these (Greenwood, 1945-1946), information is presented with regard to 228,051 treated persons, of whom 483 died of rabies. The crude percentage mortality was thus 0.21. The fatality rates are further analyzed by method of treatment and in relation to the more important variables: proportion of Europeans, species of biting animal, evidence of rabies in the biting animal, severity of bite, intervention of clothing, position of bite, delay in commencing treatment. These and other variables make interpretation of the data difficult and of limited value in assessing the failure rate of different modifications of the Pasteur treatment. While satisfactory scientific evidence of the efficacy of the different vaccines leaves much to be desired (Webster, 1942), the extremely low fatality rate among persons given any of the established methods of treatment has led to general acceptance of the concept that they afford a high degree of protection to individuals exposed to rabid animals unless the incubation period is short.

**INDICATIONS.** It is sometimes difficult to decide whether the Pasteur prophylactic treatment should be given. Treatment causes sufficient personal inconvenience, not to speak of the danger (however slight) of paralysis, to avoid advising it if unnecessary. In many cases it is impossible to discover whether the dog that inflicted the bite is mad or not. The rule is: in case of doubt advise the treatment.

Persons who apply for treatment of dog bites fall into one of the seven following categories with reference to the Pasteur prophylactic:

1. *The dog is mad; in this case, begin treatment at once.*

2. *The dog shows suggestive symptoms*: begin treatment at once; discontinue if diagnosis in the dog is established as negative.

3. *The dog is not mad*: observe it carefully for 14 days, and if no symptoms develop, there is no danger of rabies in the person bitten. The treatment is then unnecessary. (The dog may develop rabies after 14 days and if it has been bitten by another dog should be kept under control for at least six months.)

4. *The dog is not identified*: this is a common occurrence, especially with children. The rule in such cases is to advise the Pasteur prophylactic treatment, except in regions known to be free of rabies.

5. *Exposure to saliva*: persons not infrequently apply for advice giving the following history: They have not been bitten, but they have been licked on the hands and face by a dog that subsequently was discovered to have the disease. Persons are sometimes similarly exposed by washing the mouth of a rabid horse or cow. In these cases the important question is whether there were fissures or abrasions in the skin at the time. There may be little wounds in the skin not evident to the naked eye. It is possible to infect animals by rubbing the virus on the shaved skin. The rule is, therefore, to advise the protection which the treatment affords in persons thus exposed.

6. *In psychoneurotic patients* with a distressing phobia of rabies, it may afford comfort to give a mild course of treatment as much for its psychotherapeutic effect as for specific immunity.

7. *Fomites*: the question is often asked whether the disease may be contracted from contact with virus in saliva upon floors, on playthings and other objects. This situation arises with a rabid dog in the house, where children may be exposed in this indirect manner. While theoretically possible, the risk is negligible.

**Preventive Immunization of Dogs.** Practical requirements of the protective immunization of dogs are that the procedure be safe, that it confer a maximum degree of resistance for a long period of time and that it be administered in a single dose. A procedure which would seem to meet these requirements was introduced in Japan by Umeno and Doi (1921). It was used on a large scale and proved quite effective in the prevention of rabies in naturally exposed animals. The material employed was a fixed rabies virus vaccine, treated with phenol by modification of the Fermi method. It was administered by subcutaneous injection of a single dose of 5 ml.

This type of vaccine was used on a large scale in the United States during the period from 1922 to 1928. It was observed by Schoening (1925) that in extremely rare instances the vaccine could produce infection. This led to a ruling by the U. S. Department of Agriculture that rabies vaccine used for immunization of dogs must contain no active virus as determined by standard safety tests. To meet this requirement, commercial laboratories prepared a canine vaccine of the Semple type in which the concentration of brain tissue was 20 per cent. In a series of experiments, Leach and Johnson (1942) demonstrated that the chloroform-treated vaccine by Kelser when injected in dogs was found to produce a high degree of resistance to experimental inoculation. Furthermore, when stored for as long as 16 months at refrigerated temperature it still retained its immunizing capacity. The introduction of the mouse potency test led to further improvements of canine vaccines. Johnson (1945b) found that a single dose of canine vaccine of the



Simple type was an effective immunizing agent when tested in dogs and that immunity produced by a single injection of this vaccine persists for at least a year. Recently, there has been introduced a live vaccine for use in dogs prepared from a strain of rabies virus attenuated by passage in chick embryos (Koprowski and Cox, 1948). Experimental work suggests that it may confer a more durable immunity than that conferred by vaccines containing inactivated virus. From preliminary field trials, it appears that this avianized antirabies vaccine is safe and effective. Further trial is needed before judgment is passed.

**Rabies Control Procedures.** It has been demonstrated in many parts of the world that rabies can be controlled, even eradicated, in limited geographic areas by quarantine measures applied to the dog population provided wild animals are not involved in the propagation of the disease. Where rabies has once become established in wild life, as in the fox in certain eastern and coyotes in certain western parts of the United States, it has been possible to control the disease by reduction of the species affected. However, the principal reservoir in most parts of this country, as in others, is in dogs. Control depends fundamentally on measures which are directly or indirectly effective in reducing stray dogs to below the critical number required to maintain continuous propagation of the virus by passage biting. By the enforcement of ordinances designed to accomplish this reduction, rabies has frequently been temporarily eliminated from urban and suburban communities in this country. The disease has persisted in many rural areas, however, where the stray dog population is large and enforcement of control measures weak. Sooner or later, with relaxation of enforcement in the non-infected communities, an animal coming from the infected area starts a chain of transmission going again. It has not been possible to prevent such introductions by quarantine measures.

Demonstration of the value of preventive vaccination of dogs has afforded a new and extremely valuable additional means of control. By requiring mass vaccination of dogs, it is possible not only to reduce the proportion of strays but also to decrease the proportion of susceptible dogs in an area. This in turn decreases the chances of chain propagation. Vaccination of dogs, therefore, has become an important feature of the control program.

In a country as large as the United States, the problem cannot be settled by local action alone but requires nationwide cooperation.

It is currently recommended (Conference on Rabies, 1948) that the essentials of an effective control program are four: (1) recognition and definition of the responsibilities of local, state and federal agencies in dealing with the human and livestock phases of the problem; (2) adequate provision for diagnostic and treatment facilities; (3) provision for the immunization of dogs; and (4) legal authority, organization, personnel and facilities required for the control of animals capable of transmitting the disease. In connection with the latter, regulations should provide for the following specific measures in addition to requiring the annual licensing and vaccination of dogs:

- a. Proper disposition of ownerless, unwanted, and stray domestic animal pets.
- b. As soon as rabies appears in a community, strict control of all dogs should be enforced for whatever period of time may be considered necessary. Dogs should not be permitted to run at large but should be properly confined on their owner's

premises and only be permitted away from same when under proper restraint by a responsible individual.

c. Dogs which have bitten persons or other animals, and dogs which are suspected of having rabies, should be confined in a suitable, authorized place under veterinary supervision for a period of not less than 14 days.

d. Dogs known to have been exposed to rabies should be destroyed or kept confined for a period of not less than six months.

e. Dogs under six months of age, being particularly susceptible and less satisfactorily immunized than older animals, should be confined until the area is certified as officially free of rabies.

f. Adequate provisions and facilities for enforcing all regulations and requirements connected with the control program should be made available.

g. The control program should be continued for a period of at least 90 days subsequent to the last reported case of the disease in animals.

#### BAT RABIES

(*Derriengue, Mal de Caderas*)

The existence of rabies among vampire bats was recognized first in Brazil. In 1911, Carini reported the identification of Negri bodies in the brains of cattle dying of a paralytic disease called "mal de caderas." He also succeeded in infecting rabbits by the cerebral injection of brain material from paralyzed cattle. Ranchers had noted that bats were attacking and biting cattle in the daytime and that animals thus bitten died of "mal de caderas." This led Carini to suspect that vampire bats might be transmitting this disease. In 1916, Rehaag (Haupt and Rehaag, 1921) succeeded in isolating the virus from the brain of a bat. On the basis of this finding, Haupt and Rehaag concluded that the repeated epizootics of paralytic rabies that occurred among livestock in southern Brazil from 1913 to 1918 were due to rabies transmitted by vampire bats. The disease continued to spread and by 1930 had been found in Paraguay, Uruguay and Argentina to the south and up to the border of Venezuela in the north.

In 1925, a paralytic disease of livestock, including cattle, horses, mules, and donkeys, appeared in and around Port-of-Spain, Trinidad, B.W.I. During the period from 1925 to 1929 several thousand animals died of the disease, which was diagnosed as botulism. Hurst and Pawan (1932) proved by inoculation of laboratory animals the paralytic disease of livestock was due to infection with rabies virus. There had been no canine rabies in Trinidad since 1914. In 1936, Pawan reported the isolation of rabies virus from the salivary glands of vampire bats of the species *Desmodus rotundus murinus* Wagner captured in Trinidad. In another report, Pawan (1936) described the result of a study of rabies in naturally and experimentally infected vampire bats. One naturally infected bat proved capable of transmitting rabies by bite for a period of 56 days prior to its death, which was presumed to have been caused by rabies as Negri bodies were found in the brain. Vampire bats infected experimentally with rabies virus sometimes showed no signs of illness yet proved able to infect animals by bite. One of these bats was capable of transmitting rabies for a period of 83 days and subsequently died of the infection five months and 14 days after inoculation. The vampire bat is the only known host that can act as a carrier of rabies over an extended period with-



out apparent illness. de Verteuil and Urich (1936) reported an extensive study of the nature and habits of vampire bats and the epidemiology and control of vampire bats in Trinidad. Fifty-five human cases of paralytic rabies were recorded. The authors investigated 40 cases and found that with one exception there was a definite history of bat bite prior to the illness. The course of the disease in man is similar to that of canine rabies. Control measures included immunization of livestock with rabies vaccine, bat proofing of homes and stables, protective vaccination of persons bitten by bats and destruction of vampire bats. These measures proved successful in limiting the disease and no further outbreaks have been recorded in Trinidad.

Johnson (1948) studied a highly fatal paralytic disease of livestock called "derriengue" prevalent in the Pacific Coast states of Mexico. In the course of a field investigation conducted in 1944, in the states of Michoacan and Jalisco, seven localities were discovered where the disease had been prevalent in livestock in the previous six months. Vampire bats of the species *Desmodus rotundus murinus* Wagner were found in the immediate vicinity of each focus of the disease. Rabies were isolated from the salivary glands and brain of a paralyzed cow and from the salivary glands and brain of a vampire bat captured near one of the foci. The virus isolated from vampire bats is closely related to the known strains of rabies virus as shown by complement fixation and cross protection.

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## RAT-BITE FEVER

(*Sodoku, Erythema Arthriticum Epidemicum or Haverhill Fever*)

A peculiar disease of man following the bite of a rat has been known in North America for a century or more. In 1839, Wilcox published an account of "Violent Symptoms from the Bite of a Rat." Modern interest was aroused by Miyake in 1900 of a clinical entity long familiar to laity and physicians of Japan as a rat bite disease or sodoku (from "so," a rat, and "doku," poison). It is a relapsing fever with an eruption. As a rule the initial wound heals cleanly. One to three weeks later the disease begins with the development of an angry, purplish indurated area at the site of the bite. The lymph nodes which drain the area become enlarged, tender and painful. The temperature suddenly rises to 103° or 104° F and remains high for one, two, or rarely, three days, then falls to normal for a period of from four to six days. Each succeeding week is characterized by a day or two of fever followed by five or six days of normal temperature. These paroxysms of fever continue for weeks or months unless interrupted by treatment. Between the paroxysmal attacks the patient feels quite well. The rash, which is irregularly maculopapular in character and dark red or purplish in color (morbilliform or rubellaform), develops on any part or over the entire body. It appears with the first or second paroxysm of fever and tends to disappear with the fall in temperature. Severe muscle pains and occasional joint pains are usually a feature at some stage of the disease. Ultimately the patient recovers, the case fatality being extremely low unless the disease is complicated by secondary infection.

**Etiology.** Futaki, and others (1917), by inoculation of white mice with material from local lesions, enlarged lymph glands and blood, recovered and identified a spirochete; they called the organism *Spirochaeta morsus-muris*. It was probably identical with *Spirillum minus* which had been discovered in the blood of a rat by Carter in 1887 in India. The latter name has received official sanction. The organism has not been grown in artificial culture media. For diagnosis, blood taken at the height of a febrile paroxysm, serum expressed from the margin of a rat-bitten wound, juice aspirated from a regional lymph node, serum expressed from the abraded surface of a prominent macule of skin rash or a macule excised from the skin should be injected either subcutaneously or intraperitoneally into a white mouse, white rat or guinea pig, or preferably all three. The blood of the inoculated animal should be examined daily in the dark field from the eighth to the fifteenth day after inoculation or longer. The biology of *Spirillum minus* in its relationship to rat-bite fever has been systematically reviewed by Robertson (1930).

Because of suggested analogies between rat-bite fever and syphilis, arsenicals were employed in treatment and have proved to be most efficacious. One or two



doses of salvarsan, arsphenamine or similar substances are usually sufficient to bring about a cure. In the United States, artificial induction of sodoku in the fever treatment of general paralysis was begun by Solomon and his associates in 1926 and was tried by others as a substitute for malarial therapy in this disease. By the inoculation of blood from infected animals into humans, typical disease was reproduced. Antibodies were demonstrated in the blood of all patients during their illness and in several instances the *Spirillum minus* was recovered from patients' blood by inoculation of guinea pigs.

Rat-bite fever, presumably caused by *Spirillum minus*, has been reported from widely scattered areas of the world. It is particularly prevalent where a large rodent population lives in close association with a dense human population, as in Japan and India. Bayne-Jones (1931) found records of 81 cases of this disease in man in American medical literature up to 1930. This list was brought up to 1940 by Brown and Nunemaker (1942) adding 40 additional cases. Critically reviewed, however, only 17 of the 125 cases had been carefully studied by animal inoculation. Although the bite of a wild rat is by far the commonest source of human infection, some cases are unable to recall any previous injury to a localized part. Other cases have been ascribed to such unusual causes as the bite of a cat, weasel, parrot, dog or bandicoot. *Spirillum minus* has never been found in the saliva of an infected rat. The infectiousness of a rat's bite has been explained as due to the escape of blood containing *Spirillae* from an abraded or diseased bucal mucosa to the biting wound, or by the contamination of the wound by conjunctival secretions. Secondary transmission of the disease from a sick individual to another human being is unknown.

In 1914, Schottmüller described a *Streptothrix* which he cultured from the blood of a patient suffering from rat-bite fever. Subsequently, other investigators had similar experiences. In 1925, Levaditi, Nicolau and Poincloux reported a case of "acute erythema multiforme" unassociated with rat bite, from which they cultivated a micro-organism which they named *Streptobacillus moniliformis*. In January 1926, a small but explosive outbreak of illness which occurred in a restricted area of Haverhill, Massachusetts, was carefully studied by Place and Sutton (1934). They called the disease "*Erythema arthriticum epidemicum*" or "*Haverhill fever*." Eighty-six persons were affected. The clinical manifestations of the disease were similar to those of rat-bite fever but differed in that there was no local lesion, multiple recurrences of fever were not found and arthritis was a characteristic feature. There were no fatalities. Epidemiological investigation established that the vehicle of distribution was a raw milk supply. There was apparently no spread by contact of patients with other persons. The manner in which the milk had been contaminated could not be ascertained. Parker and Hudson (1926) recovered an organism in blood culture taken from 11 of 17 cases, and fluid aspirated from knee joints in two cases. From its morphology and cultural characteristics it was ultimately identified as being *Streptobacillus moniliformis*. Milk is distinctly an unfavorable medium either for growth or viability of this organism.

While there have been no further outbreaks of this type recorded, investigators have continued to report sporadic cases of rat-bite fever from which they were unable to recover *Spirillum minus* by animal inoculation but were successful in recovering *Streptobacillus moniliformis* by the use of special culture media and

technics. The latter, or closely related organisms, moreover, have also been found to be naturally pathogenic in mice and rats. These observations have been carefully reviewed by Brown and Nunemaker (1942). They concluded that ratbite fever due to *Spirillum minus* and rat-bite fever due to *Streptobacillus moniliformis* could not be differentiated by clinical observations alone. In a more recent review, Watkins (1946) believes that the evidence justifies recognition of two diseases. He advocates that distinction be made between "spirillary" and "streptobacillary" rat-bite fever, and discusses in technical detail diagnostic methods of isolating and identifying both organisms.

**Prevention.** The occurrence of rat-bite fever, although inconsequential from the point of view of the morbidity it causes, is one more reason for the suppression of commensal rats about human habitations. Treatment with penicillin is promising (Altemeier and others, 1945).

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#### LEPTOSPIROSIS

(Weil's Disease, Hemorrhagic Jaundice, Spirochaetosis  
Icterohemorrhagica, Canicola Fever)

During the latter part of the nineteenth century, it was observed that jaundice was sometimes the result of an infectious process. In 1886, Weil, on the basis of four cases which he had seen in Heidelberg, Germany, described the infectious disease which was known subsequently by his name. This condition has been, and still is, to some extent confused with epidemic jaundice or infectious hepatitis. Typically, Weil's disease is characterized by sudden onset with chills and fever, prostrations and muscular pains. About the fourth day jaundice appears in varying intensity and duration. There is an intense injection of the conjunctivae. Erythematous or papular rashes may occur. In severe cases there may be bleeding from the mucous membranes. Evidence of involvement of the kidneys is nearly always present and may progress to renal failure. Recovery begins in the second or third week. Relapse with a secondary rise in temperature lasting a week or more is not uncommon. The fatality rate, based upon cases with jaundice, is about 10 per cent. The period of incubation varies from 4 to 14 days, with a mean of about ten.

**Laboratory Diagnosis.** Investigating a disease endemic in certain parts of Japan which was similar or identical with Weil's disease, Inada and others (1916) discovered the cause to be a spirochete classified later as *Leptospira icterohemor-*



*rhagiae*. The micro-organism is recovered from the human cases by inoculation of young (200 gm.) guinea pigs or hamsters with blood obtained early in the course of the disease, or urine obtained somewhat later. Infection of a guinea pig is usually manifested by fever, loss of weight, and often jaundice. *Leptospira* are demonstrated in the heart's blood or in emulsion with the kidney or liver. They can be grown in special culture media at incubator temperature. Agglutination tests carried out with living or formalinized suspensions are valuable in confirming diagnosis. Demonstration of a significant rise in agglutination titers of paired early and late sera is evidence of the leptospiral nature of an illness. After recovery, specific agglutinins may be present in the blood for at least five years. The complement-fixation test is equally reliable for diagnosis (Gouchenour, 1952).

**Rodent Leptospirosis.** Studying the disease as it occurred in coal mines in Japan, Inada and others (1916) noted that patients were more numerous among the miners in wet than in dry mines. Clerks working outside the mines did not contract the disease. Experimentally, they demonstrated that leptospira were able to penetrate through skin even without local abrasion. They thought that infection might also occur through the alimentary canal. Although they had found that leptospira were excreted in the urine of patients during the acute illness and for some time after recovery, the distribution of cases did not suggest man to man transmission. Moreover, the disease did not occur in widespread epidemics. Following these studies, Miyajima reported that he found in *Microtus montebelli*, a vole, micro-organisms resembling *Leptospira icterohemorrhagiae* which when injected into guinea pigs produced fever and hemorrhage and, after a number of generations, jaundice. This suggestion led Ido and others (1917) to examine rats and they found virulent *Leptospira icterohemorrhagiae* in the kidneys in 40.2 per cent out of 149 *Rattus decumanus* and in *Mus* (*Rattus rattus*) *alexandrinus*. The micro-organisms cause little if any illness in rats. Entering by the mouth or skin, the leptospira localize in the kidneys and persist for weeks or months. Through excretion in the urine and contamination of food, soil or water, the organisms are transmitted from rat to rat and occasionally to other animals and to man.

The observations made in Japan were rapidly confirmed and extended by investigators in other countries. The frequency with which the infection was found in rats varied in different localities. For example, early surveys conducted in American cities revealed rates varying usually from about 10 to 40 per cent. Li and Davis (1952) found 45 per cent of 1,643 rats examined in Baltimore to be harboring these micro-organisms. In Amsterdam, 1923 to 1934, Schüffner (1934) found that of 515 adult rats, 26 per cent, and 313 young rats, 3 per cent were carriers of leptospira. Both the brown or Norway and the black rat, as well as mice, have been implicated; nor is the infection limited to these domestic rodents.

**Canine Leptospirosis.** In 1925, Okell, Dalling and Pugh, in England, discovered that canine jaundice, or "yellows" as it was known in dog kennels, was due to leptospira. Schüffner (1934) and his colleague Klarenbeek in Holland studied 50 dogs suffering from leptospirosis. Seventeen were found to be infected with *L. icterohemorrhagiae*, 28 were infected with a strain which could be differentiated by its serological reaction and by its pathogenicity. This dog strain was named *Leptospira canicola*. Meyer and others (1938) found this same strain of leptospira in dogs in California. It appears that dogs may be infected with either strain but observations thus far have failed to demonstrate *L. canicola* in rats. The pathology of

leptospirosis in dogs is similar to that in rats, the organism persisting in the kidneys and being excreted in the urine. The infection is not uncommon in the canine species. For example, Raven (1941) made agglutination-lysis tests on 105 dogs in rural Pennsylvania and found 38 per cent positive to either the rat or canine strain.

Human cases of infection with *L. canicola* have been described. For them the name "canicola fever" has been suggested. This disease is somewhat milder in its clinical manifestations than is the disease caused by the rat strain (Rosenbaum, 1946).

**Other Leptospira.** A number of other serological races of leptospira have been recovered from human and animal sources. The most important of these is *Leptospira grippo-typhosa*, the cause of the nonicteric clinical syndrome known in eastern Europe as swamp fever and in other places as summer influenza, harvest fever, mud fever, and water fever. The animal reservoir of this leptospira is unknown. Another variant *Leptospira hebdomadis* is the cause of epizootics in voles and of a "seven day fever" in Japan. These variants have not been identified in the United States. *L. biflexor* is a nonpathogenic species sometimes found in stagnant water.

**Human Leptospirosis.** Leptospirosis is world wide in distribution. By 1939 it had been reported from 46 countries. In western Europe and the United States human infection with *L. icterohemorrhagiae* from association with rats or dogs is by far the most common form, but occasionally human infection with *L. canicola* is encountered. Molner and others (1948) reviewed American literature and listed 228 cases of human leptospirosis. As clinical awareness has increased and as laboratory diagnostic methods have been more commonly employed, it has become apparent that human leptospirosis is much more prevalent than was formerly thought. In the milder forms of the disease the jaundice may be transient or absent. This is particularly true of "canicola fever." The clinical manifestations are reduced to an acute onset with chills, fever, pains in the limbs, headache, conjunctival injection, stiff neck, and recovery within a week or 10 days. These nonicteric cases escape recognition unless diagnostic laboratory tests reveal their identity. Intensive studies, such as that of Ward and Turner (1942) in Baltimore, are enlightening. Serological examination of 91 employees of nine poultry dressing establishments for agglutinations of *L. icterohemorrhagiae* revealed 13, that is, 17.3 per cent positive. The sera of three out of 48 meat packers were positive. Of 234 blood sera collected from patients in the Johns Hopkins Hospital and the Baltimore City Hospitals, 21 were found positive; only eight of these were from patients on whom the clinical diagnosis of Weil's disease had been made.

**Occupational Selection.** While leptospira die rather quickly when exposed to sunlight and drying, they will live for a period longer than three weeks in stagnant water which is neutral or slightly alkaline. Human cases of leptospiral infection arise from two general sources. The first group comprises persons whose occupations demand working in wet, rat infested places. So it has been noted to occur particularly in miners who work in wet mines, sewer workers, tunnel diggers, cutters and cleaners of fish, workers in abattoirs, poultry dressers, etc. Courts in England, Germany, and the United States have awarded compensation for Weil's disease as an occupational hazard (Stiles and Sawyer, 1942). In similar manner, infections



with *L. canicola* have been found in veterinarians and persons who live or work in intimate contact with dogs.

A second group originates from submersion or swimming in contaminated water or drinking it. In Amsterdam and other cities in Holland a considerable number of cases have been attributed to submersion by accident or with suicidal intent as well as to bathing in the water of canals which are polluted by human and animal refuse and whose banks are infested with rats. Havens and others (1941) reported an instance in which seven young men who had been swimming in a pool adjacent to rat-infested cattle barns came down with attacks of leptospirosis from 4 to 12 days later. Ward and Turner (1942) reported two cases in the same family due to drinking water from a contaminated well.

**Prevention.** Ordinarily, the disease is sporadic in occurrence. When a case occurs every effort should be made to ascertain the source of the infection and to prevent other cases arising from the same source. While community measures for the suppression of rat populations are desirable under any circumstances, efforts to effect rat control should be intensified on premises where there is an occupational hazard. The wearing of protective clothing such as waterproof boots and gloves is expedient where indicated.

Although patients may continue to excrete leptospira in the urine for some weeks after recovery, no special measures of isolation are necessary. The risk of transmission to attendants and familial associates is apparently negligible. Appropriate antibiotic therapy promises to shorten the duration of the infection.

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#### CHORIOMENINGITIS

(Acute Lymphocytic Choriomeningitis)

Armstrong and Lillie (1934) described a previously unidentified virus encountered during studies of brain material from an individual who died in St. Louis, Missouri, during the 1933 epidemic of St. Louis encephalitis. Two additional strains

of a similar virus were described by Armstrong and Wooley in 1935, one of which was isolated during studies of the brain of an individual who died in Maine, and the other from a monkey that died following inoculation with the virus of poliomyelitis. About the same time, Traub (1935) recovered a virus from his experimental stock of white mice that resembled that described by Armstrong, and expressed the opinion that the mouse was probably the natural host of the virus. Rivers and Scott (1936) reported the isolation of similar strains from two human cases of illness diagnosed as aseptic meningitis. The strains of animal and human origin were subsequently shown to be identical serologically. Additional evidence establishing the causal relationship of this virus to human disease was contributed by Lépine and others (1937) who demonstrated that by subcutaneous injection of the virus from mice, the symptoms of aseptic meningitis could be induced in human beings and the disease transmitted from man to man by means of intramuscular inoculations of infected blood. These observations were confirmed and extended by investigators in many parts of the world.

**Human Infections.** The incubation period is uncertain, but it is thought to vary from one to three weeks. The onset is sudden, frequently with respiratory and constitutional symptoms similar to those of influenza. In many patients, the illness terminates after a few days without further complications. In others, with or without a remission of fever, the first phase is followed by definite signs of meningeal involvement with headache, vomiting, stiffness of neck and photophobia, which may endure for about two weeks. Complete recovery is the rule. In the occasional case, the infection progresses to the development of definite encephalomyelitis, with mental changes, aphasia, diplopia, and paralysis. Deaths are rare. The virus can be recovered from the central nervous system and from the lungs of patients dying of the disease. The infection may occur without recognizable symptoms or as an inapparent infection.

**Laboratory Diagnosis.** When there is clinical evidence of involvement of the central nervous system, the cerebral spinal fluid shows an increase in lymphocytes up to 3,000 cm. The nature of the etiologic agent can be established by recovery and identification of the virus or by serological tests. The agent may be obtained from blood or cerebral spinal fluid early in the disease. The suspected material is inoculated intracerebrally in mice. Precautions should be taken to insure that the mice used are from a stock which is itself virus free. Guinea pigs or mice may be tested as early as the fifth or sixth day after inoculation for complement fixation with hyperimmune serum (Smadel and Wall, 1941). The virus may be propagated in tissue culture and in 11- or 12-day-old chick embryos. Serologic evidence of etiology is obtained by testing acute and convalescent phase sera for complement-fixing antibody or neutralizing antibody. The second specimen, or convalescent serum, should be collected about three weeks after the onset of illness for complement-fixation test, and about 6 to 10 weeks after onset for neutralization tests.

Acute lymphocytic choriomeningitis cannot be diagnosed by signs and symptoms alone. The nature of the illness can only be established by laboratory procedures. These are necessary in order to differentiate it from similar clinical syndromes associated with the arthropod-borne encephalitides, poliomyelitis, mumps, and other virus infections.



**Infection in Mice.** Laboratory stocks of apparently healthy mice in all parts of the world are liable to suffer from natural infection. The presence of LCM virus must always be excluded when any new viral agent is isolated by mice. Further, the virus may be passed in series unknowingly, along with another agent as a laboratory contaminant. Mortality in infected mouse stocks is less than 2 per cent. Most animals show no symptoms, although the virus is present in the blood, brain, urine, and nasal secretions. Most of the animals developing evidence of the infection, such as emaciation, drowsiness, and ruffled fur, are young, from two to six weeks old.

A mouse stock in which lymphocytic choriomeningitis was endemic was observed over a period of four years by Traub (1939). The disease persisted during this period but became so mild that it could no longer be recognized by clinical observation. In spite of this fact, all of the stock mice tested, both young and old, carried considerable amounts of virus in their organs and blood. The females readily transmitted the infection to their offspring. Intra-uterine infection became the only mode of transmission of the disease in contrast to the situation at the beginning of the observation, when a certain number of mice were born virus free and became infected by contact shortly after birth. The virus seemed to be almost perfectly adjusted to survival in mouse colonies.

Evidence that in nature gray mice, *Mus musculus*, are the natural reservoir for LCM virus was developed by Armstrong and others (1940). Gray mice trapped in the homes of four different patients were demonstrated to be active carriers of the virus. In their investigations in Washington, D. C., 52 per cent of the mice in homes in different sections of that city were found to be harboring choriomeningitis virus.

**Occurrence.** The method of transfer of the virus from mouse to man has not been definitely established, although infection through dust or food contaminated by mouse droppings seems likely. Wooley and others (1937) demonstrated antibodies by the protection test in 11 per cent of 1,248 human sera tested. These sera were obtained from inmates of federal penal institutions and from beneficiaries of the U. S. Marine Hospital. Eighteen per cent of 481 adults over 17 years of age, but only 1.2 per cent of 396 persons under 17 years of age, were positive. The occurrence of demonstrable antibodies in 117 sera from 997 individuals without history of central nervous system or meningeal involvement, suggested that immunity might result not only from the frank meningeal attack but also from either subclinical infection or a clinical condition, possibly an upper respiratory complex, not recognized as due to choriomeningitis. Since the virus of LCM was first identified, in 1934, it has been isolated in several localities in the United States, England, France, Japan, and there is evidence pointing to its presence in Africa and Ireland. It seems probable that it is world wide in distribution.

**Prevention.** Prevention of infection of human beings with LCM virus depends upon cleanliness in food preparation and storage and suppression of mouse infestation on domestic and occupational premises.

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## PSITTACOSIS

(*Ornithosis, Parrot Fever*)

Psittacosis as a disease of man was first brought to attention by Ritter's classical description of a small outbreak of "pneumotypus" at Uster, Switzerland, in 1879, at the home of his two brothers. The parrots incriminated in this outbreak were recently imported from Germany. Numerous outbreaks have been reported subsequently, the most extensive being the Paris epidemic of 1892 and the 1929-30 prevalence which invaded many countries.

Nocard studied dead birds connected with the Paris outbreak and isolated an organism, *Bacillus psittacosis*, a member of the *Salmonella* group, which he described as the causative agent in 1893. His observations were confirmed and generally accepted, and *B. psittacosis* has been isolated several times from birds and once from a human case of psittacosis at autopsy. However, during the 1929-30 outbreak independent observers, Bedson, Western and Simpson; Pesch; Krumwiede, McGrath and Oldenbusch; Armstrong, McCoy and Branham and others showed that psittacosis is caused by a filter-passing agent, a virus, which has been recovered from both birds and man.

Man usually contracts psittacosis through contact with sick birds, although apparently healthy birds may be carriers and transmit the disease. Under certain conditions this infection is extremely contagious from birds to man and is especially prone to attack those working with the experimental disease in the laboratory. Yet it is a frequently confirmed fact, first observed by Ritter, that psittacosis is but slightly communicable from man to man. At the Hygienic Laboratory in 1930, not a single contact case developed among some 200 persons variously exposed to the 11 human cases of this outbreak. A careful study of this epidemic indicates that the trouble was air-borne. The virus could readily be sent into the air when parrots preen and then shake their feathers and flap their wings.

The disease tends to appear in household outbreaks in which the case fatality rate may vary from 0 to 100 per cent. In large series of cases it usually varies from 20 to 40 per cent. There are few deaths in persons under 30 years of age, since in children and young adults the disease tends to be mild. Infection occasionally follows parrot bites or close contact, such as mouth-to-mouth feeding, but in most instances the mode of transmission is obscure.

Psittacosis has most often been confused with influenza, bronchopneumonia



or typhoid fever. Its onset is usually sudden with chilliness, fever and headache. Focal pneumonia usually becomes established during the first days of symptoms when the x-ray reveals a faint, usually circular, cloud of uniform density, situated oftenest in one of the lower lobes, with physical signs. The pneumonic spot may remain localized but in severe cases tends to spread upward while fading below and may involve the opposite lung. Cough and expectoration are usually absent or slight early but may become troublesome later. Sputum, when present, is most tenacious and difficult to expel. The tongue as a rule presents a heavy white coat, and abdominal distention is a frequent and troublesome symptom. Albuminuria is common after the first week and retention may be present; "rose spots" are occasionally noted. Leukopenia is usual during the height of the ailment. Relapses are not infrequent. Phlebitis is the commonest complication. One attack apparently confers immunity in the parrot and rabbit, but there are practically no direct data bearing upon the immunity conferred by the disease in man.

**Virus.** In the past decade, considerable progress has been made in characterizing the virus which causes psittacosis. It belongs to a group of viruses including the infective agents of lymphogranuloma venereum, meningo-pneumonitis, murine and feline pneumonitis. The group is characterized by the formation of intracellular inclusion bodies which may be seen in the infected tissues—LCL bodies of Levinthal, Coles, and Lillie. They are minute coccobacillary bodies arranged singly and in pairs, bearing a resemblance to rickettsiae and to Paschen bodies. The LCL bodies usually have a diameter of from 300 to 400  $\mu$  and are held back partially or completely by filters which allow most viruses to pass. This group of micro-organisms, therefore, appears to be intermediate between the viruses and the rickettsiae. They are readily propagated in the yolk sac of embryonated hen's eggs. Excellent antigens suitable for complement-fixation tests may be obtained by ether-chloroform extraction of yolk sac cultures. The complement-fixation test does not distinguish between the psittacosis and the lymphogranuloma agents. Mice are susceptible to infection with all members of the group when inoculated by the intranasal route and, with some, by the intraperitoneal route. Cross protection tests conducted on mice disclose strain distinctions. Manire and Meyer (1950) developed a toxin-neutralization technic with antiserum produced in chickens by hyperimmunization, on the basis of which 27 infective psittacosis agents were arranged into 6 separate and distinct groups.

The host range of psittacosis virus has been considerably extended by observations made during the past few years. Of particular importance is the implication of infection in pigeons and barnyard fowl, chickens and ducks. Table 9-3 shows the sources of cases of psittacosis in the United States from 1945 to July, 1950.

**Control.** Efforts to prevent the occurrence of human psittacosis have been principally directed toward restrictions on the importation and interstate shipment of psittacine birds by federal regulations, and restrictions placed upon breeding establishments, aviaries and pet shops by state and local regulations. These have been amended from time to time. Foreign quarantine regulations, effective December 15, 1951, provide that "Psittacine birds shall not be brought into the Continental United States, its territories or possessions (other than the Canal Zone) from any foreign country or from the Canal Zone." Three exceptions are made:

under prescribed conditions birds may be brought in for purposes of medical research, exhibition in zoological parks and by an owner if they do not exceed two in number (Federal Regulations, 1951).

Table 9-3. Sources of psittacosis in the United States, 1945 to July, 1950

Sources	1945	1946	1947	1948	1949	Jan.- July 1950	Totals	
							Cases	Deaths
Psittacine birds	35 *	13	17	21	7	5	98	1
Canaries	2	2					4	0
Linnet			1				1	0
Pet shop		1					1	0
Pigeons	33 †	12	9	9 *	4	2	69	3
Pigeons and sea gulls					1		1	0
Pigeons and chickens				2	1		3	0
Chickens			2	2	2	1	7	0
Ducks	3		1		3		7	0
Grouse	2						2	0
Pheasant		1					1	0
Several kinds of birds	1	6	3		1		11	0
Contact with birds not established	1 *	5 *	5	5 *	18	4	38	3
Laboratory infections	4	4	6	2	1		17	0
Totals	81	44	44	41	38	12	260	7

From Meyer, K. F., and Eddie, B. *Bull. of Hyg.*, 26:1, 1951, Table 2.

\* One patient died.

† Two patients died.

Restrictions on interstate transportation have been removed except that any shipment of psittacine birds must be accompanied by a permit from the health department of the state of destination, where it is required. State regulations vary greatly. In California, it has been demonstrated that with the application of scientific knowledge, psittacosis can be eradicated in parakeet breeding establishments, provided adequate funds are available for laboratory tests, for rigid supervision and for compensation of owners called upon to sacrifice their infected flock. However, even in this state where vigorous and apparently effective protective supervision of bird breeding establishments was enforced for many years, while there was a progressive reduction by control measures, new foci of infection appeared from time to time in spite of all precautions. The importation, breeding, sale, or offer of sale of birds of the psittacine family was prohibited in New York State and in New York City in 1938, but these regulations were revoked in 1952. This action was justified in part by the following considerations: Human cases are so few in number that psittacosis is a minor public health problem; effective antibiotic therapy is now available; the discovery of widespread reservoirs of the virus in other bird species, pigeons, domestic ducks and chickens, etc.; lastly, practical difficulties or impossibility of enforcing these interstate quarantine regulations. There is a question as to whether there is justification for the elaborate and expensive administrative provi-



sion necessary to supervise bird breeding establishments. Principal reliance must be placed on educating and continuously warning the public and physicians to appreciate the danger from contact with birds which may be shedding psittacosis virus.

The beneficial effects of penicillin, aureomycin, and terramycin on acute human psittacosis have been established. In birds, the antibiotics merely suppress multiplication of the infective agent but do not terminate the carrier state. The hope of ultimate control of psittacosis by eliminating avian carriers through the use of antibiotics has received little encouragement.

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### COCCIDIOIDOMYCOSIS

(*Coccidioidal Granuloma, San Joaquin or Valley Fever*)

This disease was first described in Argentina by Posadas and by Wernicke in 1892 and ascribed to a protozoan-like organism found in the tissues of the patient. In 1896, Rixford and Gilchrist gave an account of a protozoan (coccidioidal) infection of the skin and other organs in two patients who were farm laborers working in the San Joaquin Valley of California. They named the spherical organism which they observed in preparations from the tissues of the patients *Coccidioides immitis*. Following this publication, similar cases were described by other physicians in southern California, and the disease became to be known as coccidioidal granuloma. Ophüls and Moffitt, in 1900, demonstrated that the causative agent was not a protozoan but a pathogenic mold, and Ophüls, in 1905, succeeded in isolating the organism in pure culture and reproduced the disease in animals.

**Coccidioidal Granuloma.** In that region, coccidioidal granuloma became known as a chronic, progressive, highly fatal fungus disease, affecting the lungs, skin, lymph nodes, bone meninges, thoracic viscera, and other body tissues, and resembling tuberculosis in many of its aspects. Beck collected from the literature reports of 286 human cases of chronic coccidioidal granuloma. Of these, 254 occurred in California and 16 in other states. It soon became evident that most of the cases had resided in, or had traveled through, the southern half of the Great Sacramento (San Joaquin) Valley of California.

**Diagnosis.** Investigations which were conducted during this period led to the development of procedures which were of great value in identification of the infectious process (Smith and others, 1950). It was found that an antigen prepared from broth cultures, coccidioidin, was extremely useful in demonstrating allergy

to *Coccidioides immitis* by a skin test and in indicating the presence of antibodies in the serum of patients by precipitin and complement-fixation tests. Finding and identifying the causative organism in sputum, pus or tissues provided the conclusive diagnosis. A tentative identification may sometimes be accomplished by cover slip examination of suspected material, but such findings should be confirmed by cultural recovery and examination. *C. immitis* grows readily on Sabouraud's glucose agar at room temperature, but more useful differential media are now available. After four to six days' incubation, a flat membranous type of colony appears which in the course of the next week becomes covered with an abundant cottony aerial mycelium, which is at first snow white and then becomes tan brown. Microscopic examination of young cultures shows branching septate hyphae, which later fragment into numerous thick-walled rectangular, ellipsoidal or spherical arthrospores about 2.5 to 3 by 3  $\mu$  in size. These arthrospores are detached easily by jarring or shaking the culture, and numerous laboratory infections have resulted from the inhalation. This spore is the infectious form of the micro-organism. The tissue phase (spherules) has rarely been observed in artificial culture. The suspected culture should be injected into mice or guinea pigs to confirm its characteristic pathogenicity.

**San Joaquin Fever.** For at least 50 years there had also been endemic in the San Joaquin Valley a disease known as San Joaquin fever, valley fever, desert fever, or desert rheumatism. Characteristically, the illness consisted of influenza-like initial phase followed in from 2 to 18 days by an eruptive phase of erythema nodosum, less frequently of erythema multiforme, frequently associated with arthritis and conjunctivitis. The eruption lasted from six days to two weeks, and as the lesions faded pigmented areas remained for months. Recovery was practically invariable. Between 1936 and 1938, Gifford (1942) and Dickson (1938) established that this clinical syndrome was in fact the benign acute phase or primary stage of coccidioidal granuloma. Dickson suggested that the various manifestations of infection of man and animals with *C. immitis* be called coccidioidomycosis. Infection with the coccidioides fungus was thus clinically manifested in at least two ways, i.e., (1) by a primary acute infection of the respiratory tract, often accompanied by erythema nodosum from which the great majority of patients recover in a short time without complications; and (2) by a later more or less chronic granulomatous secondary phase, known as coccidioidal granuloma, which is very disabling and has a high case fatality rate.

These observations were confirmed and extended by the field studies of Charles Edward Smith (1940). Using the coccidioidin skin test, it was found that a large proportion of individuals living in the southern San Joaquin Valley reacted to this antigen, while only a small fraction gave a definite history of having suffered from erythema nodosum. Skin sensitivity to coccidioidin was demonstrable in 2 to 17 days after onset of symptoms, generally during the second week of illness. The evidence developed by observations on accidental laboratory exposures and field studies indicated that the infection might be manifested by a mild, indefinite, influenza-like attack without skin eruption or even occur without identifiable symptomatology as an inapparent infection.

**Frequency of Clinical Manifestations.** Military studies made during World War II in the 4th Army Air Field in the San Joaquin Valley of California, permits



an estimation of the frequency of the different manifestations of the coccidioidal infections (Smith, 1947). At one extreme is a completely asymptomatic or inapparent infection. Such an infection can be demonstrated only by conversion or changeover from a negative to a positive coccidioidin skin test. In the southern San Joaquin Valley, approximately 60 per cent of natural infections fell into this category. Even under conditions optimal for diagnosis, only one fourth of the infections produced clinically diagnosed disease. Around 4 per cent of infections in white males, and 10 to 25 per cent of the infections in white females were accompanied by erythema nodosum or multiforme of the classical valley fever. Approximately one in 400 coccidioidal infections, or one in 100 cases of diagnosed disease in white adult males showed the progression known as coccidioidal granuloma. The frequency of this granulomatous dissemination in Negroes was 10 times that of whites.

**X-Ray Findings.** If x-rays of the chest are taken during the acute phase of a moderately severe attack, dense shadows will usually be found in the hilar regions, indicating enlargement of the hilar glands. Radiating from the hilar region, and more widely distributed through the lung area, are densities indicating parenchymatous involvement of the various parts of the lung. These may appear in all lobes. Tuberculosis is often suspected upon the first examination but later the areas of increased density gradually decrease until in a few weeks they disappear. Occasionally, a patient with such pulmonary shadows has been sent to a sanatorium for tuberculosis when it was impossible to prove tuberculosis by recovering acid-fast bacilli or by tuberculin test. If the disease goes into the secondary progressive granulomatous stage, evidence of pulmonary cavitation may develop. The association of pulmonary calcification with healed coccidioidal infections has been recognized for some years (Cox and Smith, 1939).

**Occurrence.** One of the interesting contributions of World War II investigations was better recognition of the coccidioidal endemic areas in the United States. In California, it has been shown that, although the most highly endemic area is San Joaquin Valley, in Tulare and Kern counties, exposure to *C. immitis* is not limited to this area. Spotty endemic areas were discovered on the north extending as far as Merced County, southwest into and over the coastal range to Santa Barbara and Benventura counties and to the south and southwest in San Diego, San Bernardino and Riverside counties. To the east of California the endemic area embraces parts of the southern tip of Nevada, southwest Utah, southern and central Arizona, western Texas and southern New Mexico. Coupled with the knowledge that merely driving through an endemic area can result in infection, means that the disease must be considered in differential diagnosis by physicians in the western states and, indeed, by physicians practicing anywhere in this country.

Field studies of the endemic area of southern California indicate that newcomers rapidly acquire the infection. For example, as the result of an extensive coccidioidin testing program in Kern county schools, Gifford (1942) found that over one half of 2,718 children gave positive reactions, the percentage rose progressively from 17 per cent with Kern county residence under one year to 77 per cent with residence of 10 years or more. Although military personnel were passing through Minter Field rather rapidly in 1941 and 1942, 0.5 to 5.0 per cent of the susceptible persons were infected each month (Smith and others, 1946). The seasonal variation is related

to climate and rainfall. Maximal incidence was realized from July through October, when it was dry and dusty. Incidence is minimal through the wet winter months.

**Sources of Infection.** Clinical and pathological evidence establishes the respiratory tract as a portal of entry in nearly all cases of human infection. Rarely are cases encountered in which *C. immitis* gains entrance to the tissues through contamination of a wound. Observations on experimental animals and accidental laboratory infections have established the fact that the infective forms of coccidioides are the arthrospores. There is no evidence of transmission from man to man or from animal to animal under natural conditions. The question of where the fungus multiplies and the arthrospores originate has not been settled. The fungus has been repeatedly recovered from soil samples. Emmons (1943) has suggested that certain wild rodents, notably pocket mice, may become infected and die, and in their carcasses the mycelia develop from the spherules (sporangia) of the parasitic or tissue phase. Dogs, sheep, and cattle have also been found to be naturally infected (Stiles and Davis, 1942). Possibly other animals may harbor the fungus.

Whatever the source may be, it is apparent that in the endemic areas the minute arthrospores of the vegetative phase are widely distributed in nature. Dust is apparently the natural vehicle of dissemination. When susceptible human beings stir up dust in a highly infected area veritable epidemics occur.

**Prevention.** Avoidance of the risk of coccidioidal infection in endemic areas is an unsolved problem. Apparently, the vast majority of human beings who live in these areas gain immunity very quickly through benign natural infections of short duration. Under the special conditions which prevail in army camps in coccidioidal areas where large numbers of susceptibles are being introduced, and those infected are departing as fast as they become immune, measures directed toward local dust suppression may be warranted (Smith and others, 1946). Wherever feasible, grassing should be used. Surfacing of roads and, to a limited degree, of athletic areas is important. If turf cannot be maintained on these areas, the application of a highly refined oil may be tried. However, one should first examine the character of the soil. If the soil is a fine loose silt, success is unlikely. If it is a heavy adobe type, the procedure is more effective. Such measures, however, are not practical in a civilian community of large extent. As yet no specific drug is available for treatment.

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## HISTOPLASMOSIS

Between 1906 and 1909, Dr. Samuel T. Darling, pathologist in the Panama Canal Zone, described three cases of a fatal human infection resembling miliary tuberculosis somewhat but caused by a parasite, for which he proposed the name *Histoplasma capsulata*. His report received little attention until 1926, when a case of histoplasmosis was discovered in Minnesota by Watson and Riley. Subsequently, there were reports of cases from various localities. The studies of De Monbreun in 1934, and of others, demonstrated that the causative organism was a fungus which could be easily grown on artificial culture media of appropriate composition. It was established that histoplasmosis was essentially a systemic infection with this small yeast-like fungus. As the organism grew in various reticulo-endothelial tissues of the body, nodules were formed which tended to coalesce and caseate, producing extensive areas of necrosis, ulcers and abscess cavities.

Clinically, the disease is characterized by a gradual onset accompanied by marked evening rise in temperature, pain, either generalized or localized in the abdomen, chest, back or joints, and with gradually developing asthenia, anorexia, and loss of weight. On examination, patients might show enlargement of the liver and spleen, generalized or regional enlargement of the lymph nodes, generalized or localized abscesses or ulcers of the skin, lung abscess cavities resembling tuberculosis. Roentgenologic chest films show characteristic, persistent pulmonary infiltrations. In the advanced stage, a wide variety of symptoms are present, depending upon progression of the infection in different organs. Parsons and Zarafonetis (1945), in a review of the 71 cases which had been reported up to that time, found that the disease had been fatal in most instances. In more than four fifths of the cases the duration of symptoms averaged five months. In three cases the infection appeared to have lasted for 8, 10, and 16 years before ending fatally. Four patients were still living after intervals of two to six years. More recently, Furcolow (1950) has presented pertinent clinical and laboratory data on 16 additional cases which have been carefully studied. His case material shows variation in diagnostic certainty ranging from clear-cut, uncomplicated cases of clinical histoplasmosis, through the probable cases to those in which the finding of *Histoplasma* was incidental to the diagnosis of another disease. Of the 16 cases which he studied, five have recovered; two other cases are still classed as ill.

**Portal of Entry.** The portal of entry of the fungus is still unknown. The large number of patients who have ulcerated lesions of the mouth, pharynx and gastrointestinal tract suggest that the entrance is through the alimentary canal. There are, however, many cases in which lesions of the nose, pharynx, larynx, and lungs are present, suggesting that the respiratory tract may also be a portal of entry. Another smaller group of cases suggests entrance through the skin.

**Diagnosis.** Diagnosis is confirmed by demonstrating the organism in preparations of materials from the tissues or from sputum. *H. capsulatum* grows readily on blood agar slants at 37° C if the tubes are sealed after inoculation, and on Sabouraud's glucose agar at room temperature. It is killed at 55° C in 15 minutes and by 1 to 2 per cent formalin in 24 hours. In 1941, Van Pernois and his colleagues and Zarafonetis and Lindberg introduced the use of an intradermal test for diagnosis

of *H. capsulatum* infection. The antigen was prepared from a filtrate of a two to seven month old broth culture. In low dilution the test is not specific. Cross reactions have been demonstrated with antigens prepared from other fungi such as blastomycin, coccidioidin or haplosporangin and from *Candida albicans* (Cross and Howell, 1948). The reaction occurs within 24 to 48 hours after intradermal injection. An area of redness and edema 0.5 cm. or more in diameter is regarded as positive.

A complement-fixation test for histoplasmosis has been developed (Furcolow and others, 1948) which is more specific and dependable for diagnosis.

**Relation to Pulmonary Calcification.** Studies made in certain sections of the United States in the decade 1935 to 1945, revealed that the prevalence of pulmonary calcification was far beyond that which could be explained on the basis of tuberculosis as indicated by the tuberculin test (Gass and others, 1943). At first the view was advanced that this phenomenon represented the reversion to negative of a once positive tuberculin test. As reports accumulated, however, it became evident that the prevalence of this unexplained pulmonary calcification had a strikingly uneven geographic distribution. It was peculiarly prevalent among young people living on, or adjacent to, the western Appalachian plateau, or on the eastern slope of the Mississippi River basin and the bordering states of the western slope of the Mississippi River, i.e., the Eastern Central States. Its prevalence varied not only from state to state within the area, but some striking differences were demonstrated in counties within the state. This suggested that some condition other than tuberculous infection was responsible for this calcification.

Christie and Peterson (1945) explored the hypothesis that pulmonary calcification in tuberculin-negative persons was due to histoplasmosis. A preliminary study of chest roentgenograms and skin sensitivity to histoplasmin and tuberculin of 181 children from middle Tennessee revealed an interesting correlation between histoplasmin sensitivity and pulmonary calcification. This finding was confirmed and extended by Palmer (1946) who, on the basis of a study of the histoplasmin reactions of 8,141 student nurses, demonstrated that an area of high prevalence of positive histoplasmin reactors existed where tuberculin-negative cases of pulmonary calcification are most frequently found, in the Mississippi Valley states, including Tennessee, Kentucky, Arkansas, Mississippi, Indiana, and parts of Ohio, Illinois, Kansas and Louisiana, although the condition was far from rare in many other regions.

**Geographic Distribution.** Mochi and Edwards (1952) have reviewed the available information on the geographic distribution of (a) clinically recognized histoplasmosis and (b) of histoplasmin sensitivity. The highest rates of histoplasmin sensitivity in any region of the world have been found in the east-central part of the United States. In Canada, histoplasmin sensitivity has been found only in the southeastern provinces. A somewhat lower rate of reactors has been reported from scattered localities in Mexico, Central and South America. Practically nothing is known concerning sensitivity in Asia, except for two investigations in India which revealed a negligible number of reactors. Observations made in most European countries have failed to demonstrate any sensitivity areas, although single isolated cases of histoplasmosis have been diagnosed in Austria, Bulgaria, England, the Netherlands, Portugal, Spain and Turkey. Several cases occurred in the Union of



South Africa, which appears to be an area of low prevalence of sensitivity, but little is known of the rest of the African continent.

**Sources and Conditions of Transmission.** How man acquires the infection is not clearly understood. *Histoplasma capsulatum* has been recovered from a number of animal species: mice, rats, dogs (Emmons and others, 1955), cats, horses, skunks, opossums, woodchucks and foxes. The fungus has been repeatedly recovered and identified from soil and dust in localities associated with human cases and it has been demonstrated that spores of *H. capsulatum* can survive in the soil for several years. It has been suggested that inapparent animal infections are responsible for soil contamination. But thus far the extrahuman source of multiplication has not been identified (Emmons, 1950). The circumstances under which groups of human cases have occurred, together with the characteristics and localization of lesions in the pulmonary area, strongly suggest air-borne infection resulting from the inhalation of spores in the dust of the atmosphere (Grayston and Furcolow, 1953; Loosli and others, 1954). Thus, human infection is incidental, a terminal side chain, in the natural survival propagation of *H. capsulatum*. There is no specific drug therapy.

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## TOXOPLASMOSIS

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Toxoplasmosis is an infectious disease concerning which relatively little is known beyond its fatal course in infants. The biology, means of transmission, and even the systematic position of the causative agent is largely undetermined. *Toxoplasma gondii* is usually accepted as a protozoan, and frequently is classified with the malaria parasites among the *Sporozoa*. The multiplication by longitudinal binary fission, however, suggests a closer relationship to the flagellates so that many prefer to group it among those forms of unknown systematic position. The organism is an intracellular parasite of the cells of the reticulo-endothelial system but develops in the syncytium of the central nervous system, the parenchyma cells of internal organs, and has been found in the circulating leukocytes, and even erythrocytes.

The individual organisms are from three to six  $\mu$  in length, range in shape from round to slightly crescent-shaped spindles; usually one end of the spindle is broader and more blunt than the other giving it a piriform appearance. There is a large conspicuous nucleus in the center. Multiplication is by binary fission and repeated multiplications may completely fill the host cell, leaving only its membrane intact. The resulting accumulation has been called a cyst, pseudocyst, terminal colony, and has even been mistaken for a schizont. Upon rupture of the host cell membrane, the parasites may be found free in the blood or interstitial fluids. The organisms have not been grown on lifeless media but in tissue culture the dividing forms are suggestive of the leptomonad stages of the *Leishmania*.

Although the parasite was first discovered in birds and rodents in the tropics,\* most of the recognized human cases have occurred in the temperate zones of the United States and Europe. To what degree this is a reflection of the actual distribution of the human infection and to what degree it is merely a reflection of better differential diagnosis is not clear. The total number of clinical cases reported in medical literature scarcely exceeds 50. Although prenatal infection is the explanation offered for most, if not all, of the fatal cases in infants, and the cases of congenital chorioretinitis, it puts a heavy strain on credulity to believe that this is the only, or even the principal, means of dissemination in nature. Speculation runs the gamut from air-borne and feces-borne to arthropod transmission.

The infection has been found in a wide variety of birds and animals. Specific names have been given to the various forms from different hosts but so far there is no evidence to support the concept of different species, and considerable evidence against it. The forms are morphologically and immunologically indistinguishable one from the other, so far as they have been tested. Fatal epizootics have been reported in canaries and wild birds in Germany and among rabbits in the Dutch East Indies. *Toxoplasma gondii* has been found in birds, rabbits, and dogs in Brazil, and appeared spontaneously in a guinea pig colony in Panama. It has been found in birds, cats, and rats in the United States. In one survey in Savannah, Georgia, 9 per cent infection was found in wild rats.

Only in the severe, usually fatal, infections have the parasites been demonstrated

\* Apparently, it was first seen by Laveran in 1900 in paddy-birds in Java and first ascribed (as *T. gondii*) by Nicolle and Manceaux in 1908, from a small rodent (the *gondi*) in North Africa.



in man. The fatal cases of toxoplasmic encephalomyelitis in infants have been characterized by convulsions, hydrocephalus, cerebral calcification, and chorioretinitis. In toxoplasmic encephalitis of older children, who were presumed to have acquired the infection after birth, neither hydrocephalus nor chorioretinitis occurred. In two adults, an acute fatal exanthem with pulmonary involvement suggesting typhus fever has been described.

The uncertainty of direct microscopy or of animal inoculation in antemortem diagnosis has led to the development of several intradermal and serological tests. Using Sabin's neutralization test, Heidelman (1945) found antibodies in 17 of 27 children with congenital chorioretinitis and in six of seven mothers of such children. No more than 10 to 15 per cent of normal adults taken at random or children with pathological conditions of the eyes, other than chorioretinitis, gave positive reactions. Surveys in various parts of the United States, using Sabin's more recently developed "Methylene Blue Test" (Sabin and Feldmann, 1948), have suggested that the infection is widespread and in some cases even more than 10 per cent of the population may have circulating antibodies.

Since the usual method of transmission is unknown, it is impossible to offer intelligent suggestions for prevention. Unfortunately, no effective therapeutic agent is known. Therapeutic testing on experimental animals (Weiman and Berne, 1944) has not revealed anything more promising than the sulfa drugs, sulfapyridine and sulfadiazine.

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#### TREMATODE DISEASES

WILLIAM W. CORT, Ph.D., Sc.D.

**The Parasites and Their Life Cycle.** The trematodes that infect man may be divided on the basis of the location of the adults in the human host into liver flukes, intestinal flukes, lung flukes, and blood flukes. Only the blood flukes, or schistosomes, have a world-wide importance in disease production. The trematode diseases are very rare in North America, but with increasing contact with their endemic areas in other parts of the world the danger of their introduction into the United States has become a significant public health problem. This danger was forcibly brought to the attention of health authorities by the infection with oriental schistosomiasis of large numbers of American soldiers in the Philippines during World War II. Except for the blood flukes, the larval stages of which penetrate the skin from water, infection is from ingestion of encysted stages with food. In fact, in some cases, rather unusual food habits are involved.

The trematodes (class Trematoda) are flat worms belonging to the phylum Platyhelminthes which also includes the tapeworms. All the human forms belong to

the subclass Digenia which are internal parasites, having a very complicated life cycle involving an alternation of generations and change of hosts. The adult stages which are parasites of vertebrates, are either hermaphroditic or bisexual (schistosomes) and produce eggs which pass to the outside. The larval stage that develops in the egg (miracidium) can only continue its development in a molluscan intermediate host. The miracidium may either hatch in the open and penetrate the surface of the body of the intermediate host, or it may hatch after the egg is ingested and penetrate the wall of the digestive tract. It establishes itself in the lymph spaces of the snail and metamorphoses into the primary germinal sac (the mother sporocyst) in which the embryos of the next generation develop. These become secondary germinal sacs which, in all the important trematodes of man, except the schistosomes, have a pharynx and intestine and are known as rediae. In the schistosomes the secondary germinal sacs are elongate sacs without any trace of a digestive system and are known as daughter sporocysts. The final products of the daughter sporocysts or rediae are cercariae, the bodies of which develop directly into the adults in the vertebrate host. The development in the intermediate host provides for the production of large numbers of individuals to meet the hazards of transfer to the final host. The cercariae of all the trematodes that infect man are free-swimming and have tails. All except the schistosomes have an encysted stage (the metacercaria) which may occur either on vegetation, or other surfaces, or in the tissues of second intermediate hosts. The schistosome cercariae are able to penetrate directly the skin of the final host and have no encysted stage or second intermediate host.

**Liver Flukes.** *Clonorchis sinensis* is the most important of the liver flukes of man. Its normal habitat is the smaller bile ducts of the liver, but in heavy infections it has been found in the large bile ducts and the gallbladder, and in a few cases in the ducts of the pancreas. This parasite can develop in a number of different mammals besides man, including the dog, cat, and pig. Infection of the final host comes from the ingestion of the encysted stages in raw or improperly cooked fish. Almost 50 different species of cyprinid fish, a number of which are used as human food, have been reported as second intermediate hosts of *Clonorchis*. The snail intermediate hosts are operculate snails belonging to the subfamily Bithyniinae.

The injury produced in the final host by *Clonorchis* is centered in the liver. The development and activity of the worms in the small bile ducts produce a very great hypertrophy of their walls which, in heavy infections, interferes seriously with liver function. A large proportion of cases show no noticeable symptoms, because the host is able to compensate for the damage produced by the small number of worms that are present. In heavy infections, however, the extensive damage to the liver produces a long standing chronic disease, the chief symptoms of which are epigastric pains, diarrhea, edema and ascites with anemia, and jaundice. Extremely heavy cases are sometimes fatal.

The endemic areas of clonorchiasis are limited to the Far East, and it is especially prevalent where dishes containing raw fish are commonly eaten. The worst endemic area is in northern Indochina (Tonkin and Annam), with the highest incidence and severest disease in the delta of the Red River in central Tonkin. This parasite is also a significant health problem in south Korea and south China (Kwantung Province), and has a widespread but rather localized distribution in Japan. Although numerous individuals infected with *Clonorchis* are known to have entered



the United States over a period of many years, there is no good evidence that it has ever become established in this country.

Studies in Japan suggest that much of the infection with *Clonorchis* comes from the eating of improperly cooked fish. In Indochina and south China popular dishes containing raw fish have been implicated. In south China it has been shown that fish raised in artificial ponds are heavily infected (Faust and Khaw, 1927). They are shipped to Canton and other centers of population and are used in popular raw fish dishes.

Certain gold preparations, antimony compounds, and gentian violet have been shown to have some action against these parasites, but much further work is needed to put the treatment of clonorchiasis on a really satisfactory basis. On account of the widespread distribution of the snail intermediate hosts, and the number of domesticated and wild animals that harbor this parasite, the only practicable control method appears to be the prevention of human infection from the eating of raw or insufficiently cooked fish.

*Opisthorchis felinus* has been known for many years as an incidental parasite of man in eastern Europe. More recently, it has been found to be widespread and important in the production of disease in certain areas of the U.S.S.R., particularly in the valleys of the Irtysh and Ob rivers in eastern Siberia. Its life cycle and disease relations are very similar to those of *Clonorchis sinensis*.

*Fasciola hepatica*, the common liver fluke of sheep and cattle, has been known as an incidental parasite of man for many years. Well over 300 human cases of infection with this parasite have been reported in the literature from different parts of the world. Since the encysted stages occur on grass and other vegetation, on any surfaces exposed to water containing the cercariae, and even on the surface film of the water, human infection might be produced in a variety of different ways. The eating of wild water cress from bodies of water to which sheep or cattle have access has been suggested by several authors as a method of human infection. *F. hepatica* produces a very serious disease of sheep, and in some of the human cases severe symptoms have been present. Most human cases, however, appear not to have been very serious due probably to the small numbers of worms present. The use of copper sulphate to kill the snail intermediate hosts has proved to be a very effective method of controlling this parasite.

**Intestinal Flukes.** *Fasciolopsis buski* is the most important of the intestinal trematodes of man. The adults live in the small intestine of man and the pig. Like *F. hepatica* this trematode has no second intermediate host, and infection comes from the ingestion of the metacercariae that have encysted on the surface of water plants that serve as food for the definitive host. The snail intermediate hosts are small planorbids that live on vegetation in shallow ponds or other small bodies of water.

The severity of the disease produced by this parasite depends primarily on the number of worms that are present. Epigastric and hypogastric pains and a diarrhea, often severe, that tends to alternate with constipation, are the commonest symptoms. In heavy infections edema appears rather early and ascites is a common symptom. Untreated cases with large numbers of worms are often fatal, death apparently being due to a general toxemia.

*F. buski* has been reported as very widely distributed in the Orient. Over most

of its range it appears to be much more common in the pig than in man, although a few human cases have been reported from a number of different places. In China, there exists in northern Chekiang province a very important endemic center of this parasite where in an area of about 1,600 square miles, more than a million and a half people are infected with a large proportion of severe clinical cases. Barlow (1925) studied the epidemiology of this disease in this area and concluded that its prevalence was due to the cultivation of "water nuts," chiefly the water caltrop, *Trapa natans*, in shallow artificial ponds. These ponds are ideal habitats for the snail intermediate hosts; the eggs of the parasites are introduced in enormous numbers by the fertilization of the crop with "night soil"; and the cercariae encyst on the surface of the "water nuts." The peeling of the "nuts" with the teeth when they are eaten raw appears to account for most of the infection.

Since *F. buski* lives in the lumen of the small intestine, it is rather easily removed by a variety of anthelmintics. Barlow outlined control methods involving killing the eggs in the "night soil" by chemicals or storage, mass treatment, and attempts to modify the food habits of the people.

A large number of other species of trematodes belonging to several different groups have been reported as intestinal parasites of man. Most of them are forms which are common in other mammals and occur in man either in very limited areas or as incidental parasites. Most of these parasites appear to have little, if any, significance in the production of human disease. An exception has been demonstrated by the recent work of Africa and his co-workers (1940) in the Philippines. They found that the eggs of certain small trematodes of the family Heterophyidae that are incidental parasites of man may get into the general circulation and produce serious lesions in various organs, chiefly in the heart muscles. They concluded that these parasites were responsible for a considerable proportion of the heart disease in the patients in the hospitals in which they made their studies. In 13 cases where death was attributed to heart conditions they considered that the lesions produced by the trematode eggs were the primary cause of death. These studies open up a whole new field for further investigations, and give us a new concept of the possible importance of incidental human infection with trematodes.

**Human Lung Flukes.** The human lung fluke, *Paragonimus westermani*, lives in the lungs of man and a variety of other mammals, including the dog, cat, and pig. Infection of the final host comes from the ingestion of the encysted stages in freshwater crabs or crayfish. The intermediate hosts are several species of large operculate snails of the genus *Melania*.

The presence of the worms and their eggs produces injury to the lung tissues and walls of the bronchioles. Since, except in rare cases, only a few parasites are present in the lungs of the human host these injuries usually produce a long-standing chronic disease, characterized by a cough, vague pains in the chest, and a more or less severe hemoptysis. The young worms reach the lungs by migrating through the peritoneal cavity and penetrating the diaphragm, and can in some cases penetrate into various organs of the body where occasionally they reach sexual maturity. When present in large numbers outside the lungs they can produce severe lesions and a generalized paragonimiasis. Fortunately, this condition appears to be rare.

*Paragonimus westermani* has a widespread distribution in the Far East. Its most important endemic area appears to be southern Korea where it is a real public



health problem. It is also of considerable significance in the production of disease in certain parts of Formosa, especially among the aboriginal tribes, and in central China (Chekiang province). It also is rather widely distributed in Japan and the Philippines, but with low incidence.

A very closely related species, *P. kellicotti*, has an extensive distribution in the United States and Canada in dogs, cats, and pigs, and in certain wild mammals of which the mink is the most common. The encysted stages of this species occur only in the heart of the crayfish which serve as second intermediate hosts. It seems probable that man in this country could serve as a host of *P. kellicotti* but is protected by this peculiar location of the infective stage in a host that is not frequently eaten. Reservoir hosts appear to be more important than man in infecting the intermediate hosts of *Paragonimus*. There is no satisfactory treatment, so that the only feasible control measures appear to be to try to prevent the eating of raw or insufficiently cooked crabs or crayfish.

**Blood Flukes.** Schistosomiasis, the disease produced in man by the blood flukes, *Schistosoma haematobium*, *S. mansoni* and *S. japonicum*, is one of the most widespread and serious of all the diseases produced by animal parasites. It seems to be spreading in various parts of the world. It has recently been discovered that the larval stages of two of the three schistosomes of man can complete their development in snails in the United States, but there is no evidence that any of the three human schistosomes has ever become established in this country.

The schistosomes infect the final host by penetration of the cercariae through the skin. From the skin they make their way to the vessels of the hepatic portal system in the liver where they grow to sexual maturity in about a month. The course of migration to the liver appears to be by the blood stream. After reaching sexual maturity, the males and females copulate and migrate along the mesenteric veins to the smaller vessels where the females lay their eggs. The eggs work their way out through the wall of the intestine or urinary bladder (*S. haematobium*) and are passed in the feces or urine.

In infections with the schistosomes there is an early phase of fever and urticaria which appears to be an allergic reaction to the toxic products given off by the worms during their migrations and growth. Later injuries are related chiefly to the passage of the eggs through the wall of the intestine or bladder in their escape from the host, and to the host reaction in encapsulation of the large numbers of eggs that are retained in various tissues. While a considerable proportion of the people infected with the schistosomes show only minor symptoms on account of the small numbers of worms present, in most of the endemic areas there are large numbers of severe cases and frequent deaths.

*S. haematobium* has its worst endemic areas in the delta and valley of the Nile where a large proportion of the population is infected. It has a widespread distribution with varying incidence throughout most of Africa (Faust, 1949). It is an important parasite in Madagascar, and also occurs in Arabia, Israel, Iraq, and Iran. Recently a rapidly spreading endemic area has been uncovered in northern Syria near the Turkish border. Stoll (1947) estimated the number of cases of schistosomiasis haematobia in the world at almost 40,000,000. Because of the migration of the adult worms to the blood vessels near the urinary bladder and the lesions produced by the eggs in the wall of the bladder and nearby tissues, the pathology

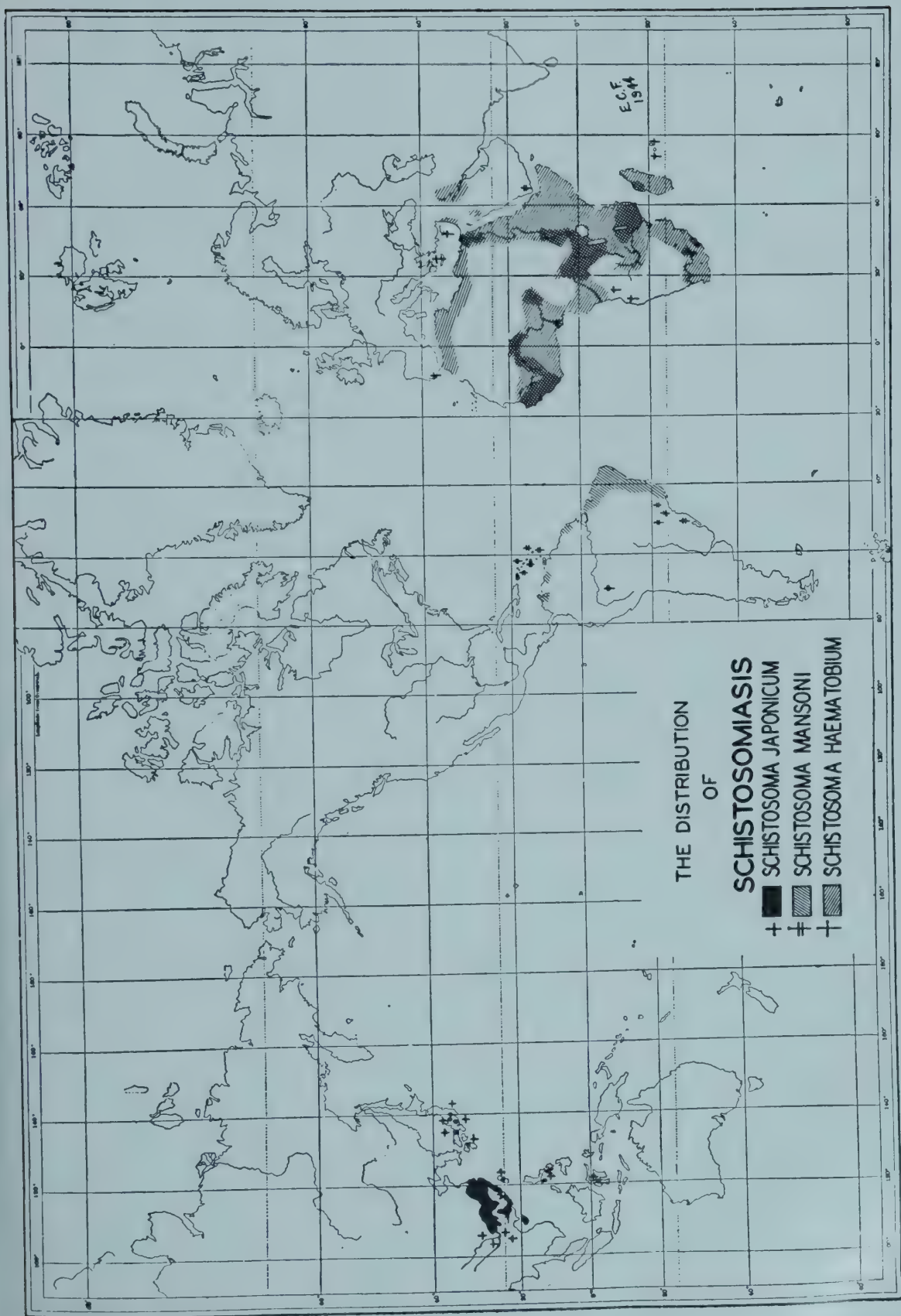


Fig. 9-1. Map showing the distribution of the human schistosomes.

From Faust, E. C., Human Helminthology. Courtesy of Lea & Febiger.



produced by *S. haematobium* centers in the urinogenital system, and the disease is frequently called vesical schistosomiasis. The lungs are frequently involved because eggs and even worms are carried to them from the vesical plexus. Except for a species of monkey in certain parts of Africa, there appear to be no significant reservoir hosts for this parasite. The typical intermediate hosts are nonoperculate snails of the genera *Bulinus* and *Physopsis* which live on vegetation in small bodies of water.

*S. mansoni* has a wider distribution than *S. haematobium* since it is found in the Western Hemisphere where it was apparently carried by slaves brought over from West Africa. In Africa, its most concentrated endemic area is the delta of the Nile. It is also widely prevalent in tropical East Africa, in the Congo Valley, and in West Africa between the Sahara Desert and the north coast of the Gulf of Guinea (see Faust, 1949, Fig. 31). In the Western Hemisphere, *S. mansoni* is a particularly important health problem in Brazil, especially in the northeastern part, where it appears to be spreading. A recent estimate gave nearly 6,000,000 people infected in this country (Stoll, 1947). This parasite is also present in Venezuela, Dutch Guiana, and in several of the West Indian Islands including Puerto Rico.

*S. mansoni* frequently has been introduced into the United States especially by Puerto Ricans, but there appear to be no authentic records of indigenous cases. Although several species of mammals have been shown to be susceptible to infection with this parasite, only monkeys have been suggested as possible reservoir hosts. The intermediate hosts are several species of planorbids. Recently, a species of *Tropicorbis* from Louisiana has been shown to be susceptible to infection.

Since the adult worms of *S. mansoni* tend to migrate to the wall of the large intestine, the lesions are chiefly in the rectum. The liver is very frequently involved on account of eggs that are swept back into it from the mesenteric veins.

*Schistosoma japonicum* is limited to the Orient (see Faust, 1949, Fig. 42). In China a vast extent of territory with a very large population including most of the Yangtze Valley is included in the areas where schistosomiasis japonica is known to be endemic. The second most important endemic areas are on several islands of the Philippines. Five small endemic areas are present in Japan and one each in Formosa and the Celebes. Stoll's (1947) estimate of the number of people in the world infected with this parasite is 46,000,000. The disease produced by *S. japonicum* is, in general, the most serious produced by the human schistosomes. Extensive intestinal lesions are present with a severe pseudodysentery and the liver involvement is very serious. This parasite differs from the other two human schistosomes in the importance of reservoir hosts. In China and Japan the use of human excrement as fertilizer is the most important factor in infecting the snail intermediate hosts. However, throughout the endemic areas infections in dogs, cats, pigs, cattle, water buffaloes, and even rats contribute to its spread. The intermediate hosts of *S. japonicum* are several species of small operculate snails, of the genus *Oncomelania*. They live in small irrigation ditches and other shallow bodies of water, and have a very considerable resistance to desiccation.

The spread of the human schistosomes, except in the few areas where reservoir hosts are important, depends primarily on close relations between the human host and bodies of water where the snail intermediate hosts find suitable habitats. The snails are infected from eggs passed into the water in feces or urine, and man derives his infection from contact with bodies of water in which the infected snails live. When

ever these relations are more or less accidental the incidence of infection is low, and the disease is mild. Agricultural practices in relation to irrigation have been very important in the spread of these parasites. In Egypt, where *S. haematobium* and *S. mansoni* are so prevalent and the diseases they produce are so severe, the system of perennial irrigation is responsible. The extensive network of canals which reaches to every field has enormously increased the habitats available to their snail intermediate hosts. Religious practices encourage urination and defecation in and near these canals. Their proximity to the houses where the people live and the methods used by the farmers in irrigating and tending the fields bring the people into constant contact with the infested water. These relations have led to the constant infection and reinfection of the population and have produced the most concentrated endemic center of schistosomiasis in the world.

In China and Japan it is the wet cultivation of rice that has made schistosomiasis so prevalent. The snails live in enormous numbers in the canals leading up to the rice fields, and are frequently present along the edges of the fields. The use of human excrement as fertilizer insures the infection of the snails, and the work in the canals and in the fields insures long and repeated exposure to infection. While there are many other sources of infection, it is among the people who raise rice that this disease is most prevalent and severe (Faust and Meleney, 1924). In some of the other endemic areas also, as in Puerto Rico, Venezuela, and parts of Brazil, irrigation canals are important sources of infection.

In recent years, the importance of the control of schistosomiasis has attracted more and more attention. Certainly, the widespread distribution and the severity of this disease, the fact that it seems to be spreading in certain areas such as the Near East and Brazil, and the inadequacy of control measures make it a very important world problem. Recently, the World Health Organization has placed investigations on the control of schistosomiasis among its most important problems. A variety of methods of attack has been suggested. Mass treatment with antimonial drugs has been tried in Egypt, but with little success. In Egypt and elsewhere where miscellaneous pollution of the water with urine and feces produces the infection of the snails, improvement of sanitation is important as a control measure. Perhaps most promising is the attempt to reduce the snail population. In Egypt, this is being done by the clearing of vegetation from the canals and in some cases by killing the snails with copper sulphate. The use of chemicals in killing the snail intermediate hosts seems to be the most promising method of control, and a great deal of work is being carried out at the present time in attempts to find new molluscicides that are adapted for this purpose.

**Schistosome Dermatitis.** A number of nonhuman schistosome cercariae are able to penetrate the skin of man and produce a dermatitis (for a comprehensive review of this subject see Cort, 1950). The most important of these dermatitis-producing cercariae are duck parasites belonging to the genus *Trichobilharzia*. It has been shown recently that this dermatitis is a sensitization phenomenon, since initial infections produce only very minute macular lesions. In individuals sensitized by repeated infections the penetration of the cercariae produces in about 10 to 15 hours discrete papules 3 to 5 mm. in diameter. The development of the papules is accompanied by an intense itching. In heavy exposures the papules may become confluent and the whole area of penetration may become swollen and edematous. On the second or



third day vesicles form on the papules which are often ruptured by rubbing or scratching. The papules usually disappear in about a week after infection.

In many places the snails that harbor the dermatitis-producing cercariae live in swamps, muddy ponds or small ditches. Under such conditions human infection occurs only infrequently. When such snails live on or near beaches that are used for bathing, large numbers of people may be infected with serious results. Under such conditions "swimmer's itch" may render whole beaches unsuitable for bathing and cause great inconvenience to summer resorters and considerable loss to resort owners. This dermatitis has a widespread distribution in the lake region of the north central United States and Canada. It has also been reported in a few places in Europe and in New Zealand. In certain parts of Malaya and Japan it is caused by cercariae from snails that live in or near rice fields. Here it becomes an occupational disease of rice farmers.

Successful control of schistosome dermatitis has been achieved on a number of infested beaches by chemical treatment to kill the infected snails (Cort, 1950). In northern Michigan its prevalence has been greatly reduced in the past 10 years. A mixture of copper sulphate (snow or finely granulated crystals) plus 10 per cent of fresh hydrated lime is used. This mixture is stirred into water (about 50 pounds to 50 gallons) and is distributed from a small rowboat by trailing rubber tubes directly on the sandy bottom where the snails live. Unless the snails are too widely scattered or live in deep water, a single treatment will usually kill most of them, and, if carefully applied, will frequently prevent the recurrence of the dermatitis for a period of three years. Beaches should only be treated when the water is calm, so that the chemical will not be dispersed before it reaches the snails.

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#### SNAKE BITE POISONING

##### (Envenomation)

Poisoning of man and domestic animals by snake bites is a biological accident, sometimes fatal, which occurs because certain reptilian species are equipped with a mechanism for capturing, killing and digesting their prey of small animals, which may be converted into a means of attack upon their predatory enemies. The frequency of this accident is determined by the number and aggressiveness of venomous species in a region relative to the human population living or working in a primitive ecology. Swaroop and Grab (1954) reviewed the reported mortality for this cause on an international basis. Though these data are relatively crude and

unsatisfactory, the highest rates are in tropical and semitropical countries (India, Burma, Thailand, Ceylon) and the lowest in the cooler climates (Finland, Norway, Sweden, Canada). The authors estimate that world-wide deaths due to snake bites are between 30,000 and 40,000 annually. Thanks to St. Patrick there are none in Ireland. Every state in the United States has at least one poisonous species of snake within its boundaries. Apparently the highest mortality rates are registered by Arizona, New Mexico, Texas and Florida.

**Venomous Snakes.** Venomous land snakes belong to two families, the Colubridae (colubrine) and the Viperidae (viperine). The more important species classified as potentially dangerous are the following:

In the Old World: the cobra (*Naja naja*), the king cobra (*Naja bungarus*), the common krait (*Bungarus candidus*), the Egyptian asp (*Naja haje*), the brown snake of Australia (*Diemenia textilis*), the Australian black snake (*Pseudechis porphyriacus*) and the death-adder (*Acanthopis antarcticus*), all of which are colubrine. Among the viperine are the daboia (*Vipera russellii*), the habu (*Trimeresurus flavoriridis*), the puff-adder (*Bitis arietans*), etc.

In the New World: the fer-de-lance (*Bothrops atrox*), the urutu or cross viper (*Bothrops alternata*), the surucucu or bushmaster (*Lachesis muta*), the neotropical cascavel (*Crotalus terrificus*), and the various species of rattlesnakes of the United States and Mexico, especially the western diamond-back rattler (*Crotalus atrox*), the eastern diamond-back rattler (*Crotalus adamanteus*), the red rattler (*Crotalus exsul*), and others, the cotton-mouth moccasin (*Agkistrodon piscivorus*) and the copperhead (*Agkistrodon mokasen*), all of which are viperine; and among the colubrine, the various elapine snakes (genus *Micrurus*).

**Venom.** In snakes, the venom glands are actually specialized salivary organs, and inoculation is effected by canalized or grooved teeth (fangs). The venom not only tends to immobilize the prey but also aids subsequent digestion of the animal tissues. It is a complex, chiefly of proteins, varying in composition from species to species. What is known about the biochemistry and mode of action of snake venoms has been summarized by Porges (1953). In general, their destructive action is due to their content of powerful digestive proteolytic enzymes—phosphatidases, hyaluronidase, opio-oxidases, lecithins—and to their paralyzing action.

**Envenomation.** The fangs in normal position are folded against the roof of the mouth. When the snake strikes they are thrown forward for the bite and the ejection of venom. Fangs are shed periodically and replaced. Venomous snakes in the United States can strike with accuracy at a distance of one half the length of the body. The amount and virulence of the venom injected varies with the species and size of the snake, the condition of the venom glands (whether full, partially depleted, or evacuated by reason of recent feeding), character and location of the bite and other factors.

After crotaline (pit viper) bites, burning pain develops at site of the injury within 5 minutes, and in 10 minutes distinct swelling develops which increases and advances to the surrounding tissues. In a serious bite on the hand, the entire arm will become extremely swollen in the first hour. The skin of the area becomes dark and purplish and bloody fluid oozes from the wound. The patient may become weak and dizzy, perspires profusely, is nauseated and sometimes vomits blood-stained material. Subcutaneous and internal hemorrhages may occur, with bleeding from



the nose, bladder and intestines. The pulse may become weak, pupils dilated and respiration difficult. Later, there may be loss of vision, paralysis, unconsciousness, coma and complete collapse. On the other hand, the venom of colubrine snakes is principally neurotoxic. Local reaction around the site of the bite is frequently insignificant. Involvement of the central nervous system is rapidly evident, with difficult articulation, nausea, vomiting and paralysis of respiration and a fatal issue within a few moments. All gradations in symptomatology occur between these two extremes.

Treatment is directed toward the accomplishment of two objectives. The first is to remove or delay absorption of the venom that is locally deposited in tissues adjacent to the bite. The second is to neutralize as far as possible the local and general effect of venom by injections of antivenin. In order to accomplish the first of these objectives, if the bite is on a limb, it is generally advised (though there is some difference of opinion, Jackson and Harrison, 1928) that a tourniquet be applied about two inches above the bite until the second measure can be undertaken. The tourniquet should not be applied tightly enough to arrest arterial circulation but only to restrict the flow in veins and lymphatic vessels. The area of the skin about the site of the bite is cleansed for surgical procedure. With a sharp blade a number of punctures or small cuts are made about the point where the fangs entered the skin. Suction is applied by mouth, cupping glass or breast pump. There is no danger from swallowed venom. Suction should continue for 15 to 20 minutes in each hour. In the intervals between suction periods, cover the wounds with sterile gauze pads saturated with sterile hypertonic salt solution. This is continued for 10 to 15 hours.

**Antivenin.** Sera containing protective substances (antivenins) against regional poisonous snakes are commercially available in many countries. For North America they are obtained from the blood of horses which have been given repeated injections of a mixture of crotaline (pit viper) venoms. Refined and dried by vacuum dehydration from the frozen state, this polyvalent antivenin may remain potent for five years. It is readily and fully soluble on addition of distilled water and may be safely and conveniently carried in the sealed vial in pocket or pack at temperatures encountered in the open. It is tested for sterility and potency and is standardized by its ability to neutralize the toxic action of a standard venom, as shown by the intravenous injection into mice. It should be administered to the snake bite victim as early as possible. Full directions for dosage and technic of injection are given in each package.\*

The patient should remain quiet. Contrary to popular opinion alcoholic drinks are of no value and may be detrimental through hastening absorption. Do not attempt to cauterize the wound with strong acids or give local injections of potassium permanganate or other oxidizing agent.

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\* Antivenin (Neurotoxic Crotalidae polyvalent) North America Snakebite Serum, published by Wyeth Laboratories, Philadelphia.

## Section Two

# NUTRITION AND DEFICIENCY DISEASES

WILLIAM H. SEBRELL, JR., M.D.

## 10

### GENERAL CONSIDERATIONS OF FOOD ELEMENTS

Good nutrition is essential for good health. Nutrition directly affects growth, development, reproduction, well-being, and the physical and mental condition of the individual. Health depends upon nutrition more than on any other single factor in hygiene.

The total number of essential nutrients required by man is still unknown since new ones are still being discovered and old ones re-evaluated, and there is suggestive evidence that others as yet unidentified also exist. Furthermore, the role of the obviously complex hormone control factors as well as alterations in enzyme systems still need elucidation. In spite of the above complexities, there is sufficient knowledge to prescribe an entirely adequate diet for man and to evaluate the effect of malnutrition on health.

The following are known nutrients required.

**Energy.** The body requires a certain amount of energy as one of its basic needs in order to sustain life. This energy is obtained by the breakdown of foods to simpler chemical substances in the process of digestion and metabolism. The unit of measurement used for this energy is the calorie. Fuel value is a term denoting the total number of calories derived from one gram of any given food if it is completely burned. Approximate fuel values used in dietary computations are four calories per gram for either protein or carbohydrate and nine calories per gram for fat. In calculating energy requirement, it is necessary to determine first the energy required for basal metabolism. This is the energy necessary to sustain the fasting individual at rest. It is related to the surface area of the body and is obtained for any given age, sex, and weight by reference to a nomogram. The basal requirement for an adult is about one calorie per hour for every kilogram of body weight. There is added to the basal requirement a factor depending on the physical exertion of the individual. This can be related to food required from tables of the caloric value of food. The lowest calorie allowance for very sedentary individuals should be about 1.2 times the basal metabolism as ordinarily measured. The normal recommended calorie allowance for the "standard" man aged 25 years, living in a temperate climate, weighing 65 kg. and engaging in moderate physical activity is 3,200 calories per day. The recommended allowance for a woman weighing 55 kg. under similar conditions is 2,300 calories per day. The individual calorie need is determined by a number of factors such as age, sex, body size, climate and activity, and the calorie allowance must be adjusted to meet the individual's needs as indicated by his weight, his change in weight and his clinical condition. Figures for various ages are given in Table 12-1, page 613. Children need more calories per pound of body weight



than adults because of the extra needs for growth. Old people need less than young adults.

**Proteins and Amino Acids.** Although proteins are the principal source of nitrogen in the diet, their primary importance is that of supplying essential amino acids which cannot be synthesized in the body. Proteins from various foods contain varying combinations of various amino acids. Proteins are, therefore, said to be of high or low biological value according to the amount of nitrogen retained, which is in turn dependent on the amino acids furnished by the food. As a rule, proteins from animal sources such as meat, milk, and eggs have a higher biological value than proteins from cereal and vegetable sources. There are 22 known alpha amino acids in food proteins. Eight of these have been shown to be essential for the maintenance of nitrogen equilibrium in man. Rose recommends daily intakes of these at about twice the highest observed minimum requirements for maintenance of nitrogen equilibrium in young male adults. The amounts recommended are l-isoleucine 1.4 gm., l-leucine 2.2 gm., l-lysine 1.6 gm., l-methionine 2.2 gm., l-phenylalanine 2.2 gm., l-threonine 1.0 gm., l-tryptophan 0.5 gm. and l-valine 1.6 gm. These amounts although recommended are not necessarily the optimum amounts. Rose's data also indicate that 80 to 85 per cent of the methionine requirement may be met by cystine and 70 to 75 per cent of the phenylalanine requirement may be replaced by tyrosine.

As a practical means of calculating a desirable protein intake, a normal adult should receive about 1 gm. of protein per kg. of body weight per day. This should be obtained from a variety of foods, some of animal origin. If a more exact calculation is desired, it must be made in terms of quantities of individual amino acids. Under ordinary conditions in this country, this is not necessary.

**Carbohydrates.** Although the body obtains energy from protein, fat, and carbohydrate, the carbohydrates are the most efficient source of fuel for muscular exercise and they constitute more than one half of the usual diet. Carbohydrate foods contain digestible carbohydrates, such as glucose, sucrose, starches, maltose, and lactose; and indigestible carbohydrates, such as pectins and plant fibers which furnish bulk to the intestinal contents as digestion proceeds. The starchy or high-carbohydrate foods are the tubers, such as potatoes; fruits and cereals; and the highly purified sugars, such as sucrose (cane or beet sugar), glucose, corn starch, syrup, and hard candy. These highly purified carbohydrates are almost completely lacking in vitamins, minerals, and all other nutritional elements except energy value. They also tend to satisfy the appetite. For these reasons they tend indirectly to create malnutrition by reducing the intake of foods of higher nutritive value. Instead of taking them in excessive amounts, they should be utilized at the end of the meal after the requirement for other nutrients has been met and when there is need to further increase the energy value of the diet.

The cereal grains such as wheat, corn, and rice form the basis of food supply of most of the people of the world. They are produced in enormous quantities and usually are the most economical source of food energy. In most areas, these cereals are refined and milled for human use in order to improve their storage qualities and to widen their range of usefulness. The outer parts of the grain contain much of the mineral and vitamin value and constitute an important source of feeds for livestock. The refined product, as a flour or meal, contains protein as well as carbohydrate

At various times governments have required the use of lightly milled products in order to improve nutritive value. Such efforts have failed so far to outweigh the desire for the highly milled product when the requirement has been removed. Another method of improving the nutritive value of these highly important foods was introduced in the United States in 1941 under the name "enrichment." This term applies to white wheat flour, white bread, and corn meal to which certain vitamins and minerals are added in order to make these products more effective in the prevention of certain deficiency diseases. This change has made a significant increase in the vitamin and mineral level of many American diets.

**Fats and Oils.** These are the most concentrated sources of energy in the diet. Since a given weight of fat furnishes more than twice the calories than the same amount of carbohydrate or protein, it is most important to reduce the fat content of the diet in treating obesity. The most important sources of fat in the diet are butter, lard, oleomargarine, fish oil, and a large number of vegetable oils such as olive oil, corn oil, and cottonseed oil. Highly refined fats such as lard and vegetable oil products, like refined sugars, have little or no vitamin or mineral value and contribute practically nothing but energy to the body. Other fats such as butter, cream, vitamin fortified margarine, and fish oil contain the fat soluble vitamins A, D, E, and K.

The fats have other nutritional importance in their "satiety" value. It has been observed that individuals on a low fat diet crave fat and suffer discomfort because of a lack of fat. In spite of these observations, it has not yet been possible to determine the human requirement for fat on a physiological basis. Estimates of need are based very largely on surveys of dietary habits. A diet of which 20 to 25 per cent of the total calories is supplied by fat is the general recommendation, with the quantity increased to 30 to 35 per cent for individuals on a very high calorie intake in order to reduce the quantity of food to be consumed.

The fats also contain unsaturated fatty acids such as linoleic, linolenic, and arachidonic acids. While it has been shown that these are required by certain experimental animals, the human requirement, if any, has not been determined. Since they occur in natural fats, they are not likely to constitute a human deficiency problem.

Fats are readily deposited in the body and in addition to serving an insulating purpose, they are the most important source of stored energy in the body. Fat occurs in all tissue and is an essential in cellular function. The phospholipids, of which lecithin, cephalin, and sphingomyelin are the principal types, are formed of fat, phosphoric acid, and a nitrogenous base. These phospholipids play important roles in metabolism and are widely distributed throughout the body.

**Inorganic Substances.** This term refers to the minerals or the contents of the ash from the body, whether present in inorganic or organic combinations. The term minerals or mineral elements is usually used to identify these substances. On the basis of quantity, the seven substances which are most important and which make up about three quarters of the ash are calcium, phosphorus, sodium, potassium, magnesium, sulphur, and chlorine. However, the quantity is no indication of the physiological importance of minerals and a number of other minerals which are present only in small amounts, and therefore called "trace elements," are known to be essential. The most important of this group of substances are iron, copper, cobalt, iodine, fluorine, manganese, and zinc. There are a number of additional minerals



of varying physiological importance such as selenium, aluminum, boron, beryllium, etc. The essential mineral elements are concerned in every chemical and physical reaction in the body. They are just as vital as the vitamins. The body needs a small but continuing intake of the elements necessary for its structure and function. If metabolic needs are not met, a deficiency ensues, producing symptoms which vary with the mineral element involved and the severity of the deficiency.

**Calcium.** Although about 99 per cent of the calcium in the body is in the bones and teeth, this element has numerous other important functions in the body. It serves as a regulator of heart muscle activity, it is essential for proper blood coagulation, for normal functioning of the nervous system, and it participates in many enzyme reactions. Thus, in addition to being needed in large amounts, it is one of the most important mineral elements and is the one which people in the United States are most likely to fail to obtain in optimum amounts. The quantity recommended for normal adults is 800 mg. and for young children is 1 gm. per day (the amount contained in about one quart of milk if this were the sole source of calcium in the diet). Adolescents, as well as pregnant and lactating women, should receive more.

The condition produced by calcium deficiency depends on the amount of vitamin D and phosphorus present, the activity of the parathyroids, and the age of the individual. Rickets, osteomalacia, osteoporosis, or tetany may occur.

Milk, cheese, and various vegetables such as turnip greens, kale, and soybeans are good dietary sources of calcium. However, a simple diet calculation of calcium does not give a true picture of whether calcium needs are being met. In some foods calcium is so tightly bound chemically, such as in the oxalate of some vegetables, that it is unavailable. Furthermore, the presence of some substances such as the phytate found in whole wheat or lightly milled flour may actually combine with and withdraw calcium from the body. Since most of the calcium excretion is by way of the intestinal tract, its rate of absorption and factors controlling absorption through the intestinal wall play a role in the calcium actually available to and retained by the body. In view of these numerous and complex factors, it is good policy to provide a large margin of safety in meeting calculated calcium needs.

**Phosphorus.** This element is interrelated with calcium and vitamin D, since the bones consist of compounds of calcium and phosphorus. It also is essential in the metabolism of protein, fat, and carbohydrate, and is found in all cells and fluids of the body. It is a constituent of many enzymes and forms a part of the molecule of the phospholipids.

Because of the interactions between calcium, phosphorus, and vitamin D, the lesions produced by phosphorus deficiency depend to some extent on the quantities of calcium and vitamin D present. Phosphorus deficiency may result in rickets or osteomalacia.

Good dietary sources of phosphorus are beans, meats, soybeans, and whole grain cereals. The allowance of phosphorus for children should at least equal the calcium. In the case of adults, the phosphorus should be about one and one-half times the calcium. As a general rule, if the calcium and protein needs are met through usual foods, the phosphorus will be sufficient since foods richest in calcium and protein are usually the best sources of phosphorus.

**Sodium.** This element serves throughout the body, and in metabolic reactions, largely as sodium chloride and sodium bicarbonate to control equilibrium, maintain

water balance, and control osmotic pressure. It is the most important cation in the extracellular fluid. Low sodium diets are useful in the treatment of hypertension. High sodium diets are required in adrenal insufficiency.

Some foods high in sodium are rye and wheat bread, ordinary salted butter, cheeses, and margarine. Since sodium chloride is used widely in cooking and appears on most tables, the requirement for sodium needs little consideration in diet planning. The average intake of salt is about 7 to 15 gm. daily. With excessive sweating 20 to 30 gm. daily may be taken.

Sodium deficiency results in loss of appetite, fatigue, nausea, and severe muscular cramps.

**Potassium.** This element must be considered in relation to sodium. A proper balance must be maintained between the two elements. Potassium is the most important cation of the intracellular fluid. The excitability of the nervous system is partly dependent on the balance between sodium and potassium. A disturbance of this balance results in alterations in water and ionic balance so that a deficiency in either element may cause important symptoms. From a dietary viewpoint a normal food supply will adequately meet the potassium needs so that it is not necessary to calculate the intake.

**Magnesium.** This element is found in the bones as well as in the soft tissues and fluids of the body. It is an antagonist to calcium to some extent, and enters into some cellular enzyme reactions. The human requirement for magnesium is small and is met by the quantity found in foods in an average diet. Some food sources of magnesium are nuts, soybeans, and cereal grains.

**Sulphur.** This element is found in insulin, glutathione, and the vitamins thiamine and biotin. It is also a constituent of the amino acids methionine and cystine. Since methionine is one of the essential amino acids, sulphur is related to protein metabolism. Inorganic sulphur cannot replace the sulphur of methionine and cystine. Protein of good biological quality in adequate amounts will meet the sulphur needs.

**Chlorine.** A large part of the chlorine in the body is found as sodium chloride in all the body fluids. The blood chlorides are important in regulating osmotic pressure and in maintaining the acid-base balance. The free hydrochloric acid of the gastric juice is essential in proper gastric digestion. The chlorides are excreted through the sweat and in large amounts in the urine.

Average diets usually contain enough sodium, potassium, and chlorine, and in the normal individual it is not necessary to make any special diet calculation for chlorine.

**Iron.** The principal functions of this element in the body are in the transportation of oxygen through its role in the formation of hemoglobin and in certain cellular enzymes such as cytochrome.

Since practically no iron is excreted from the body in the urine and feces under normal conditions, the actual daily requirement for iron is probably quite small unless loss of hemoglobin is occurring. Iron is found in the muscles and is stored to some extent in all the organs. Iron is not used up in the body, and since very little is excreted, it is used repeatedly.

Iron deficiency may result from a combination of inadequate intake and excessive loss, such as from hemorrhoids or during menstruation, or from increased demand such as growth or pregnancy.



This results in a microcytic hypochromic anemia, and in chronic cases changes in the mucosa of the lips and mouth.

The recommended daily allowance of iron for the normal adult is 12 mg. However, the absorption of iron is partly controlled by the need; therefore, the normal adult male probably absorbs very little. Good dietary sources of iron are liver, meats, beans, peas, soybeans, whole wheat flour, enriched white flour, and eggs. Since milk is a poor source of iron, infants who do not get an additional supply of iron may develop anemia around the end of the second year of life.

The iron content of a food cannot be used as a measure of the amount of iron available. The absorption of iron into the body from food depends upon the form in which the iron is present, since some organic iron salts may be unavailable for absorption; on the presence of ascorbic acid, which enhances the absorption of food iron; and on the metabolism of the intestinal mucosa.

**Copper.** Although hemoglobin does not contain copper, a trace of this element is necessary in hemoglobin formation. It is also needed in cellular respiration in the oxidases. The recommended allowance of copper for an adult is 1 to 2 mg. a day or about one-tenth the allowance of iron. Since salts of iron and many foods contain traces of copper, it is not necessary to give this element any attention in the usual diet planning.

**Cobalt.** It has been known for some time that cobalt deficiency produced an anemia in cattle and sheep and that the administration of cobalt to experimental animals would produce a polycythemia. However, the importance of traces of this element to man was not appreciated until it was shown that vitamin B<sub>12</sub> contains cobalt and that vitamin B<sub>12</sub> is effective in producing hematopoiesis in cases of pernicious anemia. Cobalt is found in organs such as pancreas, liver, and spleen. The human significance and requirement for cobalt are not known. Many vegetables contain traces of cobalt.

**Iodine.** Although this element is distributed throughout the body, it is most highly concentrated in the thyroid gland where it is combined with tyrosine to produce thyroxine, which regulates the body metabolism. Iodine is excreted in urine, sweat, and milk, and, therefore, there is a definite metabolic requirement for iodine. This requirement must be enough to maintain metabolic activity, to meet the basal daily requirement, and to maintain storage or provide some reserve. The requirement for an adult is about 0.15 to 0.3 mg. daily. This need is most easily met by the regular use of iodized salt.

A deficiency in iodine may be produced by increased demand, insufficient intake, or interference with absorption. The normal function of the thyroid gland and the formation of adequate amounts of thyroxine depend on adequate iodine. Abnormal thyroid function results in serious disturbances of growth, development, and metabolism.

The observation that certain plants contain toxic goitrogenic substances further complicates the iodine requirement. However, it has been amply demonstrated that the regular consumption of iodized salt will prevent endemic goiter, and the experimental evidence indicates that iodine deficiency is involved.

**Fluorine.** This element is found in small amounts in animal and plant tissues, and it has been found that the enamel of good teeth contains more fluorine than the enamel of carious teeth. Fluorine in the drinking water at a level of about one

part per million will decrease the incidence of dental caries. It has also been shown that in areas where the drinking water naturally contains about this level of fluorine, there is less caries than in areas where the drinking water is free of fluorine.

Fluorine in greater amounts than this (1.5 to 3.0 p.p.m.) causes the teeth to show brown stain or mottled enamel. These changes are observed only in those individuals who receive this water at the time the teeth are developing. The topical application of fluorine has also shown some benefit in preventing dental caries.

These observations have led to the recommendation that cities give consideration to the addition of fluorine to water supplies that are naturally free of it as a public health measure in the prevention of dental caries.

It should be noted that fluorine is a very toxic substance and the amounts used are very small.

**Manganese.** It has been demonstrated that manganese is an essential element for experimental animals, and that it is important in many enzyme systems. However, the human requirement, if any, is not known and there is no evidence of symptoms of a human deficiency of manganese. It occurs in traces in many foods.

## VITAMINS

About the beginning of the present century, it was recognized that essential nutrient factors were present in foods in addition to fat, protein, and carbohydrates, and in 1911 Funk coined the word *vitamine* which was later changed to *vitamin*. In 1913, McCollum and Davis demonstrated an essential nutrient in certain fats which was designated "fat-soluble A." Later, Drummond proposed that the anti-scorbutic vitamin be classified as "water-soluble C." From these diverse sources the present unwieldy alphabetical nomenclature of the vitamins naturally developed as new ones were discovered and classed as water soluble or fat soluble, although they bear no chemical relationship and most of them may be synthetically prepared and are completely identified and named according to chemical structure.

In spite of the vast body of knowledge which has been so rapidly accumulated about the vitamins, there is still no completely adequate definition. In general, they are organic substances which must be obtained either preformed or as a provitamin. They are required in small amounts; they do not furnish energy, but are absolutely essential for normal metabolic processes, and an insufficient supply results in a specific deficiency disease or metabolic abnormality.

**The Fat Soluble Vitamins.** *Vitamin A* chemically is a long chain alcohol having the empirical formula  $C_{20}H_{29}OH$ . The vitamin is known to exist in two forms: vitamin  $A_1$ , found in salt water fish and mammals; vitamin  $A_2$ , found in fresh water fish. Although there is no difference in biological activity, since vitamin  $A_1$  is the form found in mammalian liver, this is the one that is of particular interest to man.

Vitamin A may be obtained either as the vitamin or as one of the yellow or red plant pigments known as carotenoids from which all vitamin A is formed in the animal body and stored in the liver. These plant pigments are known as provitamin A. B-carotene is probably the best known of these pigments, since each molecule theoretically yields two molecules of vitamin A. In the animal body many factors influence the absorption and conversion of carotene to vitamin A. In calcu-



lating the vitamin A requirement, the carotene in plant sources should be counted as not more than half the value of vitamin A.

Vitamin A is soluble in fats, oils, and most organic solvents. It is insoluble in water and is stable to heat, but is easily oxidized. The vitamin A esters are more stable than the free vitamin, and oil solutions are relatively stable.

Vitamin A is stored mainly in the liver and may be depleted in various liver diseases. The absorption of carotene is interfered with by the presence of mineral oil in the intestinal tract. Its absorption also requires the presence of bile salts.

Vitamin A is measured in terms of international units (I.U.) which are equivalent to U.S.P. units. One international unit of vitamin A is equivalent to 0.344 micrograms of vitamin A<sub>1</sub> acetate or 0.300 micrograms of vitamin A<sub>1</sub> alcohol. The unit for the provitamin is 0.6 micrograms of B-Carotene.

The richest usual sources of preformed vitamin A are liver and fish liver oils. Swordfish liver oil may contain as much as 500 times as much vitamin A per unit of weight as the usual cod liver oil.

The green leafy and yellow vegetables are the chief sources of carotene. Examples are carrots, sweet potatoes, spinach, kale, and collards. Butter and cream contain variable amounts of vitamin A depending on the vitamin A and carotene content of the food of the dairy herd. Margarine is or should be fortified with vitamin A to the level of at least 10,000 I.U. per pound.

Only two of the several substances that have *vitamin D* activity are of practical importance. These are vitamin D<sub>2</sub> (calciferol or viosterol, which is formed by the irradiation of ergosterol) and vitamin D<sub>3</sub> formed by the irradiation of 7-dehydrocholesterol. The latter is the active form which occurs in animal fats and is produced in the skin on exposure to ultraviolet irradiation.

The D vitamins belong to the chemical group of sterols. They are soluble in fats, oils, and organic solvents.

Since foods contain very little vitamin D, it seems quite likely that exposure of the skin to the direct rays of the sun supplies much of the normal adult's vitamin D requirement. Infants and rapidly growing children should be assured of an adequate vitamin D supply either through the regular use of vitamin D milk, a fish liver oil, or one of the many concentrated vitamin D preparations available. The recommended allowance for normal children is 400 I.U. per day. The International Unit is equivalent to the U.S.P. unit (1 unit is the vitamin D activity of 0.025 micrograms of crystalline vitamin D<sub>3</sub>).

Excessively large doses of vitamin D preparations may produce toxic symptoms. These include gastro-intestinal disturbances and an increased blood calcium. If continued there may be calcium deposits in the tissues and serious damage or death.

The most important compounds which exhibit *vitamin E* activity are the tocopherols. Alpha-tocopherol has the highest biological activity. The tocopherols are liquids at room temperature, soluble in fats, oils, and organic solvents, and insoluble in water. They resist heat, but are easily oxidized.

In spite of a large amount of evidence which demonstrates the great importance of vitamin E to successful reproduction in experimental animals and its value as an antioxidant, its role in human nutrition has not been established. It has been used therapeutically in several human conditions such as habitual abortion, menstrual disorders, sterility, muscular dystrophy and heart disease, with inconclusive results.

The tocopherols occur in greatest abundance in the vegetable oils such as wheat germ oil, corn oil, soybean oil, cottonseed oil, etc.

The International Unit and the U.S.P. Unit of vitamin E are equivalent. One unit is the activity of 0.1 gm. of standard solution containing 1.0 mg. of synthetic alpha tocopherol acetate.

Several substances are known to have *vitamin K* activity. The most important are vitamin K<sub>1</sub> which occurs in the green leaves of plants; vitamin K<sub>2</sub> which has been obtained from putrefying fish meal; and menadione which is a synthetic vitamin K of greater activity than the natural vitamin K<sub>1</sub>. These substances chemically are naphthoquinones. They are fat soluble and stable to heat, but lose activity in the presence of alkali, strong acids, or on exposure to light.

Since vitamin K is abundantly distributed among the leafy vegetables, and is also synthesized in the intestinal tract, any good diet appears to meet the normal vitamin K requirement.

Bile salts are necessary for the absorption of vitamin K and deficiency may result from faulty absorption if bile salts are not present in the intestinal tract as in obstructive jaundice. Vitamin K deficiency also may occur when lipid absorption from the intestinal tract is impaired in conditions such as sprue and pancreatic disease. Vitamin K deficiency results in hypoprothrombinemia and defective blood clotting. This is especially important in hemorrhagic disease of the newborn. Vitamin K preparations are also used to reverse the prolonged clotting time induced by the therapeutic use of dicumarol.

The three most important *unsaturated fatty acids* are linoleic acid (C<sub>18</sub>H<sub>32</sub>O<sub>2</sub>), linolenic acid (C<sub>18</sub>H<sub>30</sub>O<sub>2</sub>), and arachidonic acid (C<sub>20</sub>H<sub>32</sub>O<sub>2</sub>). These substances are included in the vitamins because the early literature uses the term "vitamin F" to designate them. This has now been discarded. The unsaturated fatty acids are required by experimental animals in small amounts, but the human need, if any, is not known. They occur naturally in various fats. Linoleic and linolenic acids are found in vegetable fats and seed oils. Arachidonic acid occurs in animal fats.

**The Water-Soluble Vitamins.** *Thiamine* (vitamin B<sub>1</sub>) contains both a thiazole and a pyrimidine ring which are easily split by sulphite. As thiamine hydrochloride it is a white, crystalline, water-soluble compound with a yeasty odor. It will not stand autoclaving in neutral or alkaline solutions, but is more stable to dry heat or in acid solutions. It is soluble in water and alcohol.

The metabolically active form of thiamine is the pyrophosphate ester cocarboxylase which is a coenzyme in carbohydrate metabolism and is essential for the complete, normal metabolism of carbohydrate. In thiamine deficiency, therefore, carbohydrate metabolism is impaired and pyruvic acid accumulates. The clinical condition produced is beriberi. Thiamine is found in small amounts in a wide variety of foods. Good dietary sources are pork, legumes, nuts, whole grain or enriched flour, and oatmeal. However, the quantity of thiamine needed usually must be met from a variety of sources since no single food is likely to contain enough to make it a major source in the diet. Furthermore, the heat lability of thiamine and its water solubility may result in large cooking losses unless care is used in preparation.

The recommended daily allowance of thiamine for an adult is 1 to 1.6 mg. per day. An international unit for thiamine is no longer necessary and quantity is usually



expressed in terms of weight of pure thiamine. The old international unit is still sometimes used. This is the activity of 3 micrograms of thiamine hydrochloride.

*Riboflavin* (vitamin B<sub>2</sub>) chemically consists of an isoxanthine nucleus to which is attached a molecule of the five carbon sugar ribose. In its active metabolic form it is phosphorylated and combined with a protein to form the flavoproteins which form a part of several important enzyme systems.

Riboflavin is an orange yellow crystalline compound which forms a greenish yellow fluorescent solution in water. It is sparingly soluble in water and stable to heat. It is easily destroyed by exposure to light.

Since riboflavin is probably a constituent of every living cell, it is widely distributed in both plant and animal foods. The best dietary sources are liver, leafy vegetables, cheese, eggs, and milk. The recommended daily allowance of riboflavin for an adult is 1.4 to 1.6 mg.

*Niacin* (nicotinic acid; pellagra-preventive factor) is a pyridine derivative. It is a white crystalline compound which is soluble in water and alcohol. It is very stable and is not destroyed by autoclaving. The amide is the metabolically active form and forms part of the molecule of coenzymes I and II which play important roles in cellular respiration.

The recommended daily allowance of niacin for the normal adult is 10 to 16 mg. The requirement for niacin is conditioned by the amount of the amino acid, tryptophane, in the diet, since tryptophane may be converted in the body to niacin.

Good food sources of niacin are liver, lean meats, poultry, fish, peanuts, and dried yeast.

*Vitamin B<sub>6</sub>* is the name adopted for a group of three closely related substances—pyridoxine, pyridoxal and pyridoxamine. All three are equally effective in animals but differ in their growth stimulating effect on certain bacteria. Pyridoxine is formed in plants and pyridoxal and pyridoxamine in animals. The active metabolic form of vitamin B<sub>6</sub> is pyridoxal 5-phosphoric acid. This is the coenzyme for a large number of reactions in the transamination and decarboxylation of amino acids, especially in the reactions of the degradation of tryptophan. Vitamin B<sub>6</sub> also participates in the conversion of protein to fat and in the formation of highly unsaturated fatty acids.

The recommended intake of vitamin B<sub>6</sub> is from 1 to 2 mg. daily.

Vitamin B<sub>6</sub> deficiency in infants may upset cerebral metabolism and produce convulsive seizures.

Good food sources are liver, wheat germ, yeast and legumes.

*Pantothenic acid* (filtrate factor) is a chemical derivative of beta-alanine. As the calcium salt it is a white crystalline compound. It is soluble in water and stable to heat and oxidation. Pantothenic acid is very widely distributed in nature and is found in many tissues. In experimental rats, a deficiency results in necrosis of the adrenals; neuropathology has been observed in swine, and sudden collapse in dogs. As a part of coenzymes it participates in many metabolic reactions and appears to be an essential metabolite for all animals. A syndrome of "burning" feet in man has been attributed to pantothenic acid deficiency. Nevertheless, the human requirement, if any, is unknown.

Good food sources of pantothenic acid are liver, lean meats, salmon, soybeans, peanuts, bran, and broccoli.

*Ascorbic acid* (vitamin C) occurs as a white, crystalline compound which is readily soluble in water. It is the least stable of the vitamins and is rapidly destroyed by oxidation, especially in neutral or alkaline solution. Destruction is catalyzed by the presence of copper which accounts for the absence of vitamin C from pasteurized milk. Since milk is naturally a poor source of vitamin C, this is of no practical significance.

It occurs both as the free acid and in the oxidized form, dehydro-ascorbic acid. Both forms are physiologically active.

Ascorbic acid is a constituent of all cells. The only practical experimental animals for demonstrating ascorbic acid deficiency are monkeys and guinea pigs, since other animals are able to synthesize the vitamin. In plants it is found most abundantly in the rapidly growing portions of the plants, and synthesis takes place in relation to exposure to sunlight. The concentration is highest at the end of a sunny day. Fruits and vegetables lose their vitamin C rapidly unless refrigerated.

Physiologically, vitamin C is necessary in the organism for proper bone and tooth formation, it is related to amino acid metabolism, and is required for normal collagen formation in wound healing. The amount in the adrenal gland is under hormone control and it may play a role in erythropoiesis. A deficiency of ascorbic acid results in scurvy.

The daily recommended allowance of ascorbic acid for the normal adult is 70 to 75 mg. Good dietary sources are the citrus fruits, tomatoes, cabbage; green leafy vegetables such as kale, broccoli, and turnip greens; and other fruits such as strawberries and cantaloupes.

*Inositol* is a very stable, crystalline compound belonging to the cyclohexanes. It is widely distributed in plants as a complex inositol phosphoric acid compound called phytin. It has been shown to be required by some animals. It is not known to be of any significance in human nutrition.

*Biotin* was for a while designated as vitamin H. It is a cyclic derivative of urea, slightly soluble in water and stable to heat and acids. In experimental animals other than the chicken, raw egg white will produce the skin lesions of biotin deficiency. This is due to the presence of the protein avidin in raw egg white with which biotin combines to become unavailable and is excreted in the feces. Biotin deficiency may also be produced by the administration of an antimetabolite or by destruction of the intestinal flora.

Although humans may require biotin, it seems unlikely that biotin deficiency will naturally occur since biotin is supplied both in the food and by intestinal bacterial synthesis.

*Folic acid* (folacin; vitamin M or vitamin B<sub>9</sub>) is pteroylglutamic acid. It exists as the triglutamate or as the heptaglutamate which is the conjugated form in yeast. It occurs as bright yellow crystals which are slightly soluble in water. Solutions deteriorate on exposure to light.

In experimental animals, a deficiency in folic acid results in anemia and granulocytopenia. The human requirement has not been established. Folic acid is effective in producing a hematologic response in macrocytic anemias but the central nervous system lesions of pernicious anemia do not respond to folic acid. Vitamin B<sub>12</sub> is necessary for a complete response.



Folic acid is widely distributed in nature. Good dietary sources are liver and green leafy vegetables.

*Vitamin B<sub>12</sub>* is a bright-red crystalline compound of high molecular weight containing cobalt. It is heat stable and was originally isolated from liver. It is produced by some micro-organisms. In experimental animals it has been shown to have "animal protein factor" activity through its growth-stimulating effects on animals on vegetable protein diets. Studies on its possible growth stimulating effect on children are inconclusive.

In humans it is very effective in treating pernicious anemia and some other macrocytic anemias. One microgram is equivalent to one unit of anti-pernicious anemia activity in liver.

The human requirement is unknown.

*Choline* is a quaternary ammonium compound usually available as choline chloride which is a very hygroscopic crystalline substance with a disagreeable taste. It is stable to acid and unstable to alkali. It occurs as a part of the phospholipid lecithin.

The principal function of choline appears to be as a source of labile methyl groups. Therefore, the need for choline is related to the amount of the amino acid methionine available.

An acute deficiency of choline in experimental animals results in hemorrhage and necrosis of the kidneys. Under controlled conditions an episode of choline deficiency may be followed at a later time by hypertension. Choline deficiency results also in fatty and cirrhotic livers. It is being tried in the control of human liver cirrhosis.

The human requirement for choline has not been determined.

Good dietary sources of choline are liver, egg yolk, meats, soybeans, wheat, and oatmeal.

**OTHER WATER-SOLUBLE VITAMINS.** There are a few substances of relatively minor importance in addition to the above which are sometimes included in this classification, such as para-aminobenzoic acid, vitamin P, adenylic acid, and possibly other less well recognized substances. These are of such questionable value to man they do not warrant discussion in this chapter.

**Antivitamins.** There is a growing recognition of the possible importance of a group of chemical substances which have an antagonistic action to specific vitamins. These substances are closely related chemically to the vitamins and appear to be capable of displacing the vitamin in metabolic reactions. These substances were largely of experimental importance in studying vitamin action until one of the antagonists of folic acid was shown to have a beneficial effect in leukemia. This suggests that other antivitamins may have some practical value. Examples of vitamins and antagonists are:

VITAMIN	ANTAGONIST
Thiamine	Pyriethamine
Riboflavin	Isoriboflavin
Pyridoxine	Desoxypyridoxine
Pantothenic acid	Methylpantothenic acid
Biotin	Desthiobiotin
Folic acid	Methyl folic acid
Vitamin K	Dicumerol

**Water.** Although not usually included in dietary essentials, water is so important to the nutritional well-being of the individual that it must not be neglected in dietary calculations. In normal individuals the sensation of thirst is usually a guide. Water should not be restricted unless there are medical indications for this. A usual allowance of water for adults is 2.5 liters daily. Much of this is obtained in foods. Under unusual conditions of heat, work, and sweat, requirements may go very high—up to 13 liters daily.



# 11

## MALNUTRITION

Malnutrition is a very broad term meaning any one of many manifestations of any type of disorder in the nutritional state of the individual. Thus, obesity as well as starvation is a form of malnutrition. Malnutrition presents itself in a varied series of disease conditions according to the specific nutrient involved. It is most frequently seen as a complex clinical syndrome presenting a confusing mixture of symptoms due to a simultaneous deficiency in several specific nutrients. Nevertheless, the symptoms of the various deficiencies are sufficiently well defined for specific diagnosis to be made.

It is frequently assumed that the only cause of malnutrition is a failure to consume an adequate diet because of unavailability of food. This unwarranted assumption may be the cause of missing the diagnosis in many cases of malnutrition. Although economic factors, famine, ignorance, bad dietary habits, and similar causes may lead to widespread malnutrition in large population groups, there are many other causes that must be taken into consideration which result in serious malnutrition in the presence of an apparently adequate food supply. Thus, such apparently simple things as lack of teeth, food allergies, mental conditions, and alcoholism may all result in failure to eat available food and produce malnutrition. The presence of other disease is a most important factor in producing malnutrition, and many of the most serious cases seen in this country occur as complications of other diseases. Such diseases as hyperthyroidism may increase the need for nutrients. Diseases of the intestinal tract producing diarrhea, nausea, anorexia, achlorhydria, or other changes such as occur in tuberculosis, malignancy, liver and gallbladder disease, pregnancy, etc., may interfere with absorption or utilization, or result in increased excretion and thus produce malnutrition.

The most important forms of malnutrition are as follows:

1. **Underweight and Starvation.** In its extreme form, this is the most obvious form of malnutrition and results from a continued calorie deficiency. With a deficient energy intake, the body must utilize its own fat and other tissues, producing loss of weight and, in children, stunted growth and development. In serious starvation there is a reduction in metabolic rate, a slowed and weak pulse, a lowered blood pressure, loss of body fat and wastage of muscle, decreased muscle tone, loss of skin elasticity, mental dullness, and easy fatigue. In many famine situations diarrhea is common, but the cause is not clear. In extreme starvation edema appears in the dependent portions of the body and increases as the starvation proceeds until the body is severely waterlogged and body weight determinations are useless. Death frequently occurs from heart failure even after remedial feeding has been started.

The possible importance of mild degrees of emaciation, especially in children and as complications of diseases, has not been determined and may be difficult to detect. Tables of age, height and weight are not very helpful in assessing the individual, although they may be very useful statistically. This is because of the variations which occur in the size of the bones and in the relation between weight of organs and musculature in relation to weight of body fat. If the subcutaneous fat is gone and the skin is thin and lacking in elasticity, an early stage of underweight should be suspected and further evidence sought. In this connection accurate information on the previous body weight is important since a rapid loss of a considerable amount of weight (in the absence of a clearing edema) constitutes a more serious clinical situation than a very slow loss. In cases of starvation the symptoms of specific deficiencies in vitamins and minerals are likely to be minimal.

Children usually make good recoveries from partial starvation and recover their lost weight. Adults recover very slowly and complete recovery is a matter of months. Mental changes are variable. In extreme starvation, care must be used in early feeding and milk, if available, is well tolerated. Overfeeding may cause death and intravenous injections may result in pulmonary edema or death from heart failure.

**2. Obesity and Overweight.** In the final analysis this may be as serious a form of malnutrition as starvation. The true medical importance of obesity is just being appreciated. In this country it is perhaps the most prevalent form of malnutrition. Its importance bears a direct relation to age. The older the individual, the more important that he not be loaded with an excess of fatty tissue.

The basic cause of obesity is the reverse of the cause of starvation. It is the continued intake of food in excess of that needed to meet the energy requirements of the body. The reasons why individuals eat more food than they require are very complex and appear to be deeply involved in dietary habits perhaps established in youth, to mental and emotional problems involved in frustrations and emotional relief obtained from the sense of gratification supplied by an overly full stomach, and various other factors.

The diagnosis of obesity requires more than a casual glance at the patient. Various postural abnormalities and certain diseases may give the patient an appearance resembling obesity superficially when the patient may actually be emaciated. It should be determined that the patient is actually carrying an excess of adipose tissue.

The prevention of obesity is much easier than its treatment. It requires an appreciation of the importance of the condition, frequent accurate determinations of body weight and restraint in food consumption if fat is accumulating. It involves educating the public to realize that overeating may be as bad as undereating.

The only treatment for obesity of any consequence is to reduce the caloric intake enough to create an energy deficit. The rate of loss of weight is controlled by the amount of the energy deficit. Although this sounds simple, it is very difficult to achieve success unless the patient has a real urge to reduce and to stay thin. This means that basically the underlying emotional factors which created the obesity must be corrected or overcome by a greater urge such as a fear of early death. Exercise and medication are merely useful adjuncts of limited value.

**3. Protein Deficiency.** Protein deficiency may be either acute or chronic. An acute deficiency may result from a severe hemorrhage, an extensive burn or severe



injury, or large exudation or transudation of body fluid. In acute severe protein loss, there is shock and there may be circulatory collapse. Chronic protein deficiency follows a period of negative nitrogen balance which may be caused by inadequate protein intake; or by some condition creating increased protein catabolism; or by interfering with absorption or utilization such as intestinal obstruction, chronic diarrhea, liver disease, steatorrhea, etc. In most instances, the clinical picture is one which also involves starvation. There is anorexia, secondary anemia, weight loss, and weakness. The skin loses elasticity, wounds do not heal well, ulcers appear, diarrhea is common. The plasma protein level is lowered. In the severe stages edema appears in dependent portions of the body and is at first transient, later increasing until it may involve the entire body. This is accompanied by severe muscle wastage. Prevention and treatment involve supplying adequate protein of good quality. In treatment the same precautions must be observed as in starvation. Intravenous feeding is dangerous in severe cases. Protein hydrolysates, milk, transfusions, amino acid mixtures, etc., may be used freely to supply the necessary protein with due caution about overfeeding severe cases.

4. **Vitamin A Deficiency (Xerophthalmia).** This vitamin has several important functions in the body and a deficiency produces symptoms related to these disturbed functions. Vitamin A is necessary for normal bone growth. Since it is a component of the visual purple of the retina, it is essential to normal vision. It is also essential for the normal functioning of glandular and epithelial tissue. In vitamin A deficiency, secreting epithelium tends to keratinize and cease functioning, resulting in a wide variety of symptoms.

In humans one of the common symptoms of vitamin A deficiency is hemeralopia or night blindness. This is an interference with vision in dim light related in all probability to interference with formation of the visual purple of the rods of the retina.

Skin changes consist of a follicular hyperkeratosis which may appear first on the extensor surfaces of the thighs and the lateral surface of the forearms. The face, back, and chest may be involved also. Comedones and small pustules may occur. Eye lesions result from changes in the lacrimal gland which cause drying and thickening of the conjunctiva: Bitot's spots, followed by swelling and redness of the eyelids; photophobia; secondary infections; ulcers and panophthalmia with blindness. In very serious cases the interference with normal epithelial function may result in bronchopneumonia, middle ear and kidney infections. Prevention consists of including in the diet foods containing vitamin A or carotene in the needed amounts. The essential in treatment is the administration of large doses (25,000 to 100,000 I.U.) of vitamin A daily to adults, accompanied by dietary correction. If complicating disease is contributing to the deficiency, it must be corrected.

5. **Rickets (Vitamin D Deficiency).** Rickets is a chronic nutritional disorder of the young, characterized by changes in the bones. Rickets is characterized by an alteration in the structure and growth of bones, which become enlarged at the extremities and so soft that they bend under the weight of the body. It occurs during the first two years of life, when growth is rapid. The symptoms develop gradually, and when well advanced the disease is characterized by restlessness and night sweating, delayed dentition, softening of the skull bones, and flabby muscles. Rickets is responsible for bowed legs, knock knees, flatfeet, and saber legs, and is associated

with the rickety rosary, pigeon breast, square head, and pot belly, a strange medley that finds its most exaggerated expression in misshapen dwarfs.

Rickets constitutes one of the important diseases of infancy on account of its prevalence, its serious complications and sequelae, and the fact that it is readily preventable. Deformity of the bones of the pelvis produced by rickets in childhood is one of the causes of difficult labor, and may result in fetal or maternal death.

Rickets first manifested itself in Europe in the sixteenth century. The reason is obvious. Populations, particularly in England—a country never noted for its abundance of sunlight—were attracted to city life with its impoverished diet and bad housing. Rickets became so prevalent by 1650 as to call forth Glisson's famous monograph on the subject. It was not until 1885 that Pommer described its pathology.

Rickets occurs mostly in cities. It began in the cities of Europe and later appeared in North America. In India it is found as osteomalacia among the upper classes, due to "purdah," or the custom of keeping women with their children permanently in darkened houses; the lower classes, even with a restricted diet, are spared because they live so much in the sun. It is not infrequent in northern Africa, for example in Algiers, as well as in northern China. In Japan it is very common.

The poor suffer most, although the children of the well-to-do are not spared. Rickets is much more prevalent than is indicated by the meager figures found in vital statistics. It does not appear in the mortality tables because it is seldom a direct cause of death.

Rickets begins to increase in the fall, becomes more marked in the winter, and reaches its peak in March; it then declines steadily, and new cases rarely develop after June. Rickets is most frequent during the second half of the first year of life or the first half of the second year. It often occurs earlier, but is not congenital. Premature infants are notably predisposed to rickets, probably on account of their exceptionally rapid rate of growth. To a less extent this is true of twins.

In the temperate zones, rickets is more frequent among colored and dark-skinned races than white on account of the pigment armor against the effect of sunshine. As is well known, Italian and Negro babies in our large cities are especially prone to develop this disorder.

The earliest symptoms are restlessness, irritability, and head sweating—signs which are suggestive rather than indicative. Soon thereafter, enlargement of the costochondral junctions (the rachitic rosary) develops. The head becomes somewhat square in shape, the fontanel is too widely open, the areas of softness may be felt along the lower part of the occipitoparietal suture. The epiphyses at the wrist may be enlarged and radiographs disclose changes in the ulna typical of rickets. There is a decrease in serum phosphorus and an increase in alkaline phosphatase. All these signs are not present in every case. Radiographic changes in the ends of the long bones are characteristic but do not appear early. The rachitic process must have been developed for some months before the lesions can be demonstrated by the roentgen ray.

The well-developed or advanced case presents a picture which is evident at a glance. The head is square, the thorax deformed, showing two lateral rows of visibly enlarged costochondral junctions and a groove traversing its lower part (Harrison's groove). The abdomen is large and protuberant—the well-known "pot belly"; con-



stipation rather than diarrhea is the rule. The legs are bowed or knock-kneed and the ligaments lax. The infant may no longer be well-nourished, for the extreme cases are associated with retardation in growth and weight.

The majority of cases are mild; so mild indeed that many pass unrecognized and leave no local deformity or systemic disturbance. Recovery comes about spontaneously as the result of the fortuitous advent of spring or summer, or the decrease in rate of growth. Bowed legs, beading of the ribs, and enlarged epiphyses gradually disappear and the bones regain their normal contour in most cases. However, these signs may persist, as well as the square head, the deformed chest, the scoliosis, kyphosis, flatfoot, etc.

The cause of rickets is a deficiency in vitamin D brought about by failure to expose the skin to the ultraviolet rays of the sun. Under modern conditions in temperate climates this is usually not practicable in the wintertime and a dietary source of vitamin D is necessary if rickets is to be prevented. The full-term infant should receive 800 I.U. daily of vitamin D during the first year of life; during the second year, 400 I.U. daily. Premature infants require larger amounts. In treatment, 4,000 to 5,000 I.U. daily may be used for as long as 5 to 6 weeks. Some cases of refractory rickets may require much larger dosage.

One of the most useful forms of vitamin D in preventive medicine is vitamin D milk, which is now available in most cities in this country, and contains 400 I.U. of vitamin D per quart. This is available either as fresh, dried, or evaporated milk and offers a simple, practical, and economical method of ensuring a regular intake of vitamin D, which can be supplemented by medicinal preparations of higher potency when indicated.

Osteomalacia is the adult counterpart of rickets in infants.

**6. Hemorrhagic Disease of the Newborn (Vitamin K Deficiency).** Since vitamin K is usually supplied from synthesis by intestinal bacteria as well as from the diet, there is little evidence of vitamin K deficiency in adults except in conditions where there is interference with lipid absorption such as chronic ulcerative colitis, steatorrhea, etc. Normal absorption requires the presence of bile salts in the intestinal tract and, therefore, obstructive jaundice may produce vitamin K deficiency. The essential difficulty in vitamin K deficiency is a hypoprothrombinemia, which prevents normal blood clotting. The lack of bacterial synthesis of vitamin K in the intestinal tract of the newborn infant probably explains the hypoprothrombinemia usually seen. In an occasional infant this results in hemorrhages during the first week of life called "hemorrhagic disease of the newborn." The condition may be prevented by parenteral administration of 1 mg. of a vitamin K preparation to the mother during the last week of pregnancy or just before delivery or to the infant at birth.

Treatment consists of giving a vitamin K preparation if there is a prolonged prothrombin time and a hemorrhagic tendency.

**7. Beriberi (Thiamine Deficiency).** The clinical descriptions of severe beriberi in the older literature probably include symptomatology from multiple deficiencies, although the most prominent findings were the result of thiamine deficiency. The underlying defect in thiamine deficiency is a deranged carbohydrate metabolism. Thiamine is essential for the formation of cocarboxylase. If there is insufficient cocarboxylase, the carbohydrate intermediate pyruvic acid begins to accumulate in abnormal amounts in the system and other metabolic derangements also probably

occur. This derangement in carbohydrate metabolism appears then to lead to a variety of symptoms depending on the severity of the deprivation of thiamine and the acuteness of withdrawal.

Just as in the other deficiencies, thiamine deficiency may occur either as a result of insufficient intake or from factors in the body influencing absorption, destruction, utilization, or excretion. Since thiamine is necessary for normal carbohydrate metabolism, the administration of glucose parenterally in large amounts should be accompanied by administration of thiamine or deficiency symptoms may be precipitated in a thiamine-depleted individual. A diet high in refined sugar and starch requires the presence of adequate thiamine. A diet high in fat requires less thiamine.

The symptoms of thiamine deficiency may be classified as neurological, cardiac, and gastro-intestinal.

The earliest symptoms of thiamine deficiency are referable to the central nervous system. The symptoms are those of neurasthenia, loss of attention, irritability, vague fears, emotional disturbances, etc. This is followed by a peripheral polyneuritis beginning as a hyperesthesia and paresthesia of the extremities, especially the toes and feet, which may become quite severe. There is tenderness and weakness of the calf muscles, and the patient has difficulty in rising from a squatting position. Loss of the ankle jerk reflex and loss of vibratory sense over the great toe and malleoli may appear early. In severe cases the condition progresses to wrist or ankle drop with muscular atrophy and serious disturbance in walking.

The cardiac symptoms in the early stages are those of tachycardia, shortness of breath, heart consciousness and dizziness, and irregularities in the heart beat. The heart rate may be slowed. The electrocardiogram usually shows a decrease in amplitude or an absence of the T-wave. In more advanced cases, edema of the extremities appears which becomes extensive with serous effusions and signs of congestive heart failure, accompanied by right-sided dilatation of the heart and enlargement of the liver. This serious stage of the disease may lead to sudden circulatory collapse and death. Patients with beriberi should be kept in bed in order to avoid an unexpected circulatory failure and death.

The gastro-intestinal symptoms are less important than the neurological and cardiac. They consist of loss of appetite, indigestion, constipation, and occasionally vomiting. The x-ray shows atony and dilation of the bowel.

Infantile beriberi is a serious condition and in some areas is a leading cause of infant mortality. It may occur in a nursing infant if the mother is depleted of thiamine. The mother may be free of gross clinical symptoms of beriberi.

The prevention of thiamine deficiency is theoretically simple, but practically difficult. Beriberi is most prevalent in those areas of the world where rice is the staple cereal, although it is now known to occur widely in mild form in many other areas where refined carbohydrate foods constitute a considerable item of the diet. It is well known that if brown, unpolished rice is substituted for polished rice beriberi will be prevented due to the thiamine content of the outer layers of the rice. In areas of the world where other cereals predominate, the whole cereal supplies more thiamine than the refined product since as a general rule the thiamine in the cereals is concentrated in the germ and the outer coatings of the crude grain. However, in spite of vigorous efforts to substitute the brown rice for white rice this has never succeeded for a variety of reasons, among them poorer keeping qualities which



interfere seriously with storage and a social factor in addition to taste preference. These difficulties led to efforts to popularize and extend the use of parboiled rice which is a satisfactory product and has met with some limited success. A new development which offers considerable promise is the work of Salcedo in the Philippines, who has shown it is practical to add thiamine to white rice and that this "enriched rice" is acceptable and most effective in controlling beriberi. This "enrichment" of white rice is now required by law in the Philippines. This is an extension to rice of the procedure used in the United States for "enriching" white flour and corn meal in order to improve their thiamine content without altering the desirable features of the refined product. Other methods of reducing the prevalence of beriberi consist of education and attempts to include in the diets foods containing thiamine.

The treatment of beriberi requires the administration of thiamine in doses of 10 to 50 mg. daily by mouth or parenterally, depending on the severity of the case. It should be used with care intravenously since a few deaths, apparently of an anaphylactic type, have been reported.

8. **Ariboflavinosis (Riboflavin Deficiency).** Riboflavin is a constituent of several enzyme systems and occurs probably in all the cells of the body. It functions in the metabolism of both carbohydrates and proteins. The mechanism by which the deficiency symptoms are produced is unknown. The symptoms may be classified as ocular, oral, and dermal.

The ocular symptoms are essentially those of an interstitial keratitis. There is photophobia, lacrimation, and injection of the vessels of the cornea with a complaint of a gritty feeling of the eyes. A mild photophobia may be an early symptom. In severe stages the patient cannot stand light at all because of the pain and the condition may superficially resemble a severe conjunctivitis. There is a circumcorneal injection of the vessels and slit lamp examination reveals extension of numerous capillaries from the limbic plexus into the cornea. Corneal opacities appear and may become dense with almost total blindness. Such opacities, if recent, show remarkable improvement on riboflavin therapy.

The oral lesions consist principally of changes in the lips. The mucosa of the lips becomes denuded, shiny, reddened, and scaly, resembling a "chapped lip." In addition, a macerated area appears in each angle of the mouth, followed by the development of a small transverse fissure which tends to extend onto the face rather than into the mouth. These fissures have been designated "angular stomatitis" and the entire lip lesion has been called "cheilosis." In some cases the tongue takes on a magenta hue.

The dermal lesions are seborrheic in nature and usually appear as greasy flakes over an erythematous base and are seen in the various folds of the body, especially the nasolabial folds, the canthi, behind the ears, the axillae, and groin. They may become secondarily infected and involve considerable areas of the body. In many cases filiform excrescences appear and project from the sebaceous follicles across the nose and cheeks, especially producing what has been called "shark-skin."

The riboflavin requirement is usually met from a number of food sources. Prevention is accomplished by supplying riboflavin-containing foods. In the United States, the use of riboflavin to "enrich" white flour makes a significant and cheap source. Milk and green leafy or yellow vegetables are other important sources.

Treatment requires the administration of 15 to 20 mg. of riboflavin daily in divided doses.

9. **Pellagra (Niacin Deficiency).** Although this disease is basically due to a deficiency in niacinamide, its occurrence is also controlled by the amount of tryptophane in the diet since the quantity of this amino acid that is present affects the need for niacinamide. This has led to much confusion in attempts to relate diet composition to the occurrence of pellagra.

As in beriberi, the older clinical literature gives a description of the symptoms of pellagra which in the light of present knowledge was a multiple deficiency state. The neurological symptoms were probably due to thiamine deficiency and the condition called "pellagra sine pellagra" appears to have been riboflavin deficiency. It should always be kept in mind that the clinical picture in deficiency disease is most likely to be a multiple deficiency state. It seems desirable to use the designation "pellagra" for the clinical syndrome produced as a result of niacin deficiency, although in practice it is recognized that the case may have symptoms of other deficiencies simultaneously.

Outbreaks of pellagra resembling epidemics occur in localities with restricted food conditions; sporadic cases may crop out anywhere and have a world-wide distribution. A marked feature in the United States is the high prevalence in late spring and early summer, following the limited winter diet. Under unfavorable dietary and economic conditions in endemic localities, pellagra recurs year after year, giving a false impression of chronicity. *Black tongue*, a disease in dogs, resembles pellagra pathologically, and is due to dietary defects similar to those which cause the disease in man.

The digestive symptoms of pellagra are dyspeptic disturbances and later stomatitis. Nervous manifestations begin with weakness, vertigo, and insomnia. About 2 per cent of pellagrins develop mental disturbances requiring institutional care. The skin eruption is the most characteristic sign. It begins as an erythema, usually bilateral and symmetrical, affecting especially the backs of the hands and forearms, the face and neck, feet and genitalia. The symptoms vary greatly in severity. Fully developed cases present a characteristic picture.

Sporadic or endemic pellagra has now been reported from nearly all parts of the civilized world. In Europe, the disease has long prevailed in Portugal, Spain, Italy, and Rumania, while the northern countries have been slightly if at all affected. Pellagra also is unevenly distributed in America. It has prevailed especially in the southern part of the United States and some of the West Indies, while Canada, Mexico, and South America have remained well-nigh free. The areas of the world most affected are the northern part of Italy, Rumania, lower Egypt, Yugoslavia and in the United States the regions south of the Ohio and Potomac Rivers.

Endemic areas have widely contrasting conditions of climate and soil. In the United States, the prevalence is in the late spring and early summer. There is no special race susceptible. In some localities the white and in others the colored pellagrins predominate.

The disease may develop at any age, but is rarely seen during the first year of life. It attacks both sexes about equally during childhood and adolescence, but many more cases are seen in adult women than in men.

Sporadic cases may occur anywhere at any time, even in well-to-do families.



These are due to eccentricities of diet, food fads, gastro-intestinal diseases, chronic alcoholism, deranged mentality, or other conditions which cause the diet to become one-sided, restricted, monotonous, and faulty in one or more respects.

In Europe, the disease attacks almost exclusively the peasant farm laborer. In the endemic area in the United States, it also has a marked rural distribution but is not restricted to the agricultural population. Indeed, with us, pellagra has prevailed extensively in certain types of rural industrial communities, such as cotton mill villages, mining and sawmill camps.

The symptoms of niacin deficiency are glossitis, gastro-intestinal disturbances, and skin lesions. In mild cases the glossitis may be manifested only by reddening of the tongue with loss of papillae. In acute cases there is a severe burning sensation in the mouth. The tongue becomes very bright red and sore and denudation of both tongue and cheeks occurs with pseudomembrane formation and the picture is one of severe acute stomatitis resembling an extensive Vincent's infection of the mouth.

The earliest symptoms of niacin deficiency are loss of weight, weakness, mental depression, and gastro-intestinal distress with gaseous eructations and indigestion. This is followed by diarrhea or alternating diarrhea and constipation, with more distressing indigestion, nausea, and vomiting. Gastric analysis shows an achlorhydria.

The dermal lesions are most characteristic. In old chronic and mild cases the pressure points, such as elbows and knees, show dry, scaly, darkly pigmented areas which may also involve the legs or forearms where the skin assumes a thin, cracked appearance called "pavement epithelium." The acute case begins like a sunburn with an acute erythema. This goes on to desquamation or to bullae formation followed by desquamation. The lesion is fiery red, painful, and usually becomes secondarily infected. It is most frequently bilateral on the extremities or appears across the face or around the neck. The genitalia are frequently involved. The skin lesion has a sharp line of demarcation from the normal skin and becomes heavily pigmented during healing. The pigmentation may persist for a long time after the lesion has completely healed.

Many cases show mental changes characterized by depression, fear, confusion, and impaired memory. These lesions may go on to a major psychosis. Another type of mental change is an encephalopathy with cogwheel rigidities, grasping and sucking reflexes, and disorientation.

Prevention of niacin deficiency requires foods containing either niacin or tryptophane. Thus milk, although low in niacin, is a very useful preventive because of its tryptophane content. Enrichment of corn meal and white flour with niacin has made a widespread valuable contribution to the niacin content of diets in the United States.

In treatment, niacinamide or niacin should be used in daily doses of 150 to 500 mg. by mouth. In cases with encephalopathy larger doses given parenterally are required. Niacinamide is usually preferred to niacin since the latter gives a flushing reaction which is uncomfortable but apparently harmless.

10. **Scurvy (Vitamin C Deficiency).** Scurvy is a typical deficiency disease due to lack of the specific food factor vitamin C. It is a disorder of nutrition, usually brought on by the prolonged lack of fresh food in the ration, and is characterized by debility, anemia, a spongy condition of the gums, and a tendency to hemorrhages. The lesions occur especially in the bones and the blood vessels. The essential pathology is failure to form and maintain intercellular substance.

Scurvy occurs independently of age, sex, and general vitality, if the diet is deficient. It may develop in vigorous adults and even in the aged, but it is especially prevalent in infants because of the monotonous one-sided diet of cow's milk or some proprietary food lacking in the specific vitamin.

Scurvy ordinarily is caused by a lack of fresh fruit and vegetables in the diet. The potato is the mainstay against scurvy during the winter months in some countries. Foods lose their vitamin C on aging; fresh vegetables are superior to those which have been dried or stored for long periods. If foods are protected from oxidation during canning there should be little loss of vitamin C. This is especially true of the acid foods such as tomatoes. In cooking, foods should be protected from exposure to air; soda should not be used; cooking water should not be discarded; cooking time should be as short as possible; foods should not be beaten (such as mashing potatoes) and should be served as soon as possible after preparation if vitamin C is to be retained.

Severe adult scurvy is relatively rare in the United States. It apparently requires several months of severe vitamin C deprivation to produce the severe clinical condition. It is not clear how much lesser degrees of deprivation have to do with the occurrence of chronic gingivitis, pyorrhea, and similar conditions.

Severe adult scurvy begins with weakness, loss of weight, and muscle pains. The gums are swollen and hemorrhage freely and the teeth become loosened. Hemorrhages occur in all parts of the body on the slightest trauma. There may be severe nose bleed, hematuria, and cerebral or retinal hemorrhages. Slight skin trauma results in the appearance of "bruises." Death may occur from heart failure on exertion.

Infantile scurvy presents a different picture and is much more prevalent. It occurs almost exclusively in artificially fed infants and most frequently under one year of age. The symptoms are irritability, anorexia, and loss of weight, with pain on movement or on handling. The child does not voluntarily move the extremities because of pain. Hemorrhages are usually found under the periosteum of the bones which produces swelling which does not involve the joint. Hemorrhages may occur anywhere in the body. Enlargements are usually found at the costochondral junctions resembling rickets. X-ray examination reveals a typical picture with thickening of the epiphyseal line at the ends of the long bones where growth is most rapid.

In prevention, all infants should be given a source of vitamin C from the first month of life. This may be given as one to two ounces of unheated orange juice starting with one teaspoonful daily in the first weeks and rapidly increasing the amount. If this is not tolerated or is unavailable, 25 to 50 mg. of ascorbic acid may be used.

In treatment of infantile scurvy, 300 mg. daily by mouth should produce rapid improvement. The dose may be reduced after the first week. Adults should be given 1 gm. daily for the first week in divided doses, then 500 mg. a day as long as necessary.

**11. Liver Cirrhosis.** There is now much evidence to indicate that portal cirrhosis (Laënnec's cirrhosis) is basically caused by malnutrition, although the condition may be aggravated by alcohol. Experimentally, the condition is produced by a diet deficient in choline or in choline precursors, the most important of which is the amino acid methionine. Choline is a lipotropic agent and, if deficient, fat



accumulates in the liver followed by an increase in connective tissue and a diffusely scarred, nodular liver, with serious interference to liver function. Many cases show symptoms of multiple deficiencies, especially of the vitamin B complex, as complications of the symptoms due to the cirrhosis.

In treatment, the diet should be high in protein (140 gms.) supplemented by daily oral doses of 2 to 5 gm. of either choline or methionine and by dried brewers yeast, one ounce twice daily. The diet should be low in fat and cholesterol, but should meet calorie requirements. The presence of signs of vitamin deficiency may require other specific vitamin treatment.

**12. Macrocytic Anemias.** This group of anemias includes pernicious anemia, the macrocytic anemia of pregnancy, sprue, celiac disease, etc. They appear to be nutritional in origin in the sense that they occur as a result of defective blood formation, either from failure to receive, absorb, or utilize extrinsic factor (vitamin  $B_{12}$ ), or an absence of intrinsic factor which is responsible for the absorption of extrinsic factor. Extrinsic factor (vitamin  $B_{12}$ ) and erythrocyte maturation factor appear to be identical. In pernicious anemia the essential difficulty is a lack of intrinsic factor in the gastric mucosa which interferes with absorption of extrinsic factor from the diet. Lack of extrinsic factor prevents the normal development of the red cell which is stopped at the megaloblast stage.

Nutritional macrocytic anemia is due to a diet deficient in the extrinsic factor (vitamin  $B_{12}$ ), folic acid or both.

In the macrocytic anemias of intestinal diseases such as sprue or celiac disease the defect may be lack of absorption of extrinsic factor (vitamin  $B_{12}$ ).

The role of the pterolyglutamates (folic acid) still needs explanation. It is effective therapeutically in causing regeneration of erythrocytes, and in the macrocytic anemia of pregnancy it is effective (5 to 15 mg. daily) although parenteral liver extracts and vitamin  $B_{12}$  are not effective.

Uncomplicated pernicious anemia should be treated with parenteral administration of 15 to 30 micrograms of vitamin  $B_{12}$  once or twice weekly and recovery followed by a maintenance dose of 15 to 30 micrograms once every two weeks.

**13. Iron Deficiency Anemia.** This is the traditional nutritional hypochromic microcytic anemia resulting from iron deficiency. It must be recognized that there must be blood loss or increased iron demand as in pregnancy so that the body store of iron is depleted for this form of anemia to occur. Its occurrence under simple conditions of low iron intake with no loss must be very rare. However, since chronic blood loss can occur in many insidious ways, the occurrence of iron deficiency anemia is very common.

Symptoms are pallor, weakness, irritability, appetite disturbances, brittle fingernails, fissures at the angles of the mouth, hemic heart murmurs, indigestion, etc. Examination of the blood reveals a greater loss of hemoglobin than of red cells which are small in size and pale.

The prevention is to include adequate iron in the diet and reduce or stop the blood loss. The treatment is administration of iron salts such as ferrous sulphate (0.2 gm. three times a day after meals). This will result in rapid regeneration of hemoglobin. Other defects in dietary habits and other deficiency symptoms should, of course, be corrected.

14. **Kwashiorkor.** This dietary disease of unknown etiology is probably the most important form of malnutrition in the world today on the basis of mortality and prevalence. It is found widely among African natives where it was first recognized by Proctor in 1926 and described in West Africa by Cecily Williams in 1933. The condition is also widespread in India, Malaya, the West Indies and in Central and South America. It occurs primarily in infants and small children on grossly deficient diets low in good quality protein.

The clinical signs are retardation of growth, edema, hypoproteinemia, scaly pigmented skin lesions, depigmentation or dyspigmentation of the hair, anemia, enlarged fatty liver and decreased serum amylase. An atrophic pancreas may be found at autopsy. The mortality is high. The total clinical picture may be an electrolyte imbalance and multiple vitamin deficiency superimposed on an underlying amino acid deficiency and imbalance. The basic cause seems clearly associated with amino acids or good quality protein. The most effective treatment is skim milk to which other dietary essentials are added as indicated and the child's condition permits.

Prevention consists in maintaining a diet with adequate protein of good quality such as milk, meat and fish.

15. **Goiter.** This is a chronic enlargement of the thyroid gland due to a variety of causes. Disorders of the thyroid are most frequent in regions where the iodine content of food and water is low. Factors, however, other than iodine deficiency may cause goiter. As in other deficiency diseases, an iodine deficiency may occur even though the intake appears to be adequate. This can occur from a variety of causes such as an unusually high requirement, failure of adequate absorption, poor utilization, etc. Also in the case of iodine, it is known that the presence of cyanate will lower the iodine content of the thyroid. The excessive use of foods high in cyanate such as cabbage or the use of medicine containing cyanate may result in goiter.

The thyroid regulates the rate of metabolism, controls growth, is necessary for the normal development of the brain, stimulates sexual development at puberty, maintains normal pregnancy, and controls production of an adequate milk supply during nursing.

The thyroid gland, of all the body tissues, has an affinity for iodine. Iodine taken into the body is combined with the amino acid tyrosine in the thyroid to form diiodotyrosine. Two molecules of diiodotyrosine combine to form the hormone thyroxine. This may be used or combined with protein and stored as thyroglobulin. Iodine is absolutely essential for the formation of thyroxine. The thyroid gland normally contains 15 to 20 mg. of iodine.

There are three disease states due to disturbed function of the thyroid gland: (1) hypothyroidism, (2) hyperthyroidism, and (3) simple goiter.

The two important hypothyroid conditions are cretinism and myxedema.

A cretin is a child dwarfed by a lack of sufficient thyroid secretion during fetal life. Myxedema is similar, but less severe, and occurs from thyroid insufficiency at any time after birth. In cretins the mental, physical, and sexual development is greatly retarded. If they live to be adults they retain their childhood body build and may not mature sexually. If untreated, their mentality may be arrested at a low level. They have a low metabolic rate, the skin has a typical thick dry appearance, and



deaf mutism is common. If thyroid extract is given at an early age marked improvement results, but complete recovery does not always occur. Cretinism should be prevented by an adequate supply of iodine for the mother before and during pregnancy.

Myxedema results when the thyroid is destroyed, or degenerates for any reason. There is a loss of vigor, the hair becomes dry and brittle, there is apathy and lethargy, and the skin becomes thickened due to accumulation of a semi-fluid albuminous material. Thyroid extract will completely control the symptoms of myxedema.

Hyperthyroidism is an enlargement of the thyroid gland with increased functional activity. The chief symptoms are rapid heart beat, exophthalmic goiter, tremor and nervousness, high blood pressure, elevation of temperature, and increased rate of metabolism. The symptoms are associated with increased activity of the thyroid gland and the condition is, therefore, also called thyrotoxicosis. Secondary toxic goiter also follows simple goiter as a complication. Usually, hyperthyroidism does not occur until after 15 years of simple goiter. The simple adenomatous goiter becomes a toxic adenomatous goiter for unknown reasons. If simple goiter is avoided by adequate iodine intake we would not have any secondary toxic goiter.

Simple goiter is by far the commonest form of goiter, and occurs in all parts of the world. Goiter areas exist, often separated only from the next area by a change in the watershed, or the supply of salt.

The enlargement which occurs in simple goiter may be accompanied by a mild degree of hypothyroidism, or underactivity. The enlargement represents an effort to manufacture adequate amounts of thyroxine.

Simple goiter begins with a lessening in the amount of iodine in the colloid and an increase in the size and number of the thyroid cells. The first stage is called parenchymatous goiter. When hyperplasia spreads evenly through the whole gland, the resulting goiter is symmetrical and firm. Parenchymatous goiter may go on to a complete exhaustion, or wearing out of the cells; or the increasing process may stop, and the follicles become filled with colloid.

When the latter happens, a colloid goiter results. Colloid goiters are usually symmetrical and somewhat soft. They may be very large, because each of the many additional follicles becomes distended with colloid. The total quantity of iodine in the entire gland may be close to normal, but because of the enlarged size, the ratio of iodine per gram of gland tissue is low.

Another kind of goiter is called an adenomatous or nodular goiter. Either parenchymatous or colloid goiter may gradually change to adenomatous goiter, which is the commonest type of goiter after the age of 30. Asymmetrical, or uneven, bulges or nodules form. They may increase in size from that of cherry stone to plum stone or larger.

Simple goiter is so called because it does not cause any toxic or poisoning symptoms. Its importance from a medical standpoint is due to the fact that nodular or adenomatous goiter may frequently have its origin in a pre-existing colloid goiter, and when this occurs nodular goiter may subsequently become toxic; also, symptoms due to pressure on neighboring structures such as the windpipe may occasionally be bothersome in patients with colloid goiter. From a health standpoint, colloid goiter is completely preventable by taking a small but adequate amount of iodine in the

food regularly. Where iodized salt is used from infancy, simple goiter, with very few exceptions, is avoided.

From ancient times goiter has been known to exist in certain regions. It occurs throughout the world wherever the supply of iodine is inadequate. Iodine is especially lacking in glaciated regions away from the sea. The classic home of simple or endemic goiter is in the Swiss Alps. The disease is prevalent in all of Switzerland, northern France, northern Italy, and the Balkan states. The traditional seat of goiter in England is in Derbyshire ("Derbyshire neck"), while Sussex and Hampshire have also been affected. There are many endemic centers in the Himalayan Mountain regions of eastern and southeastern Asia, the Gilgit district of northern India, and the plateau regions of western China and Mongolia. In South America, it is found in the Andes regions, the most noted section of which is the Peruvian plateau. Goiter also occurs in Africa, Central America and Mexico. In Japan, the malady is infrequent, probably because the people regularly partake of marine plants which are rich in iodine. The early explorers found goiter among the North American Indians. The region of our Great Lakes shows considerable numbers; also sections of the Middle West and parts of the Rocky Mountains, but in the United States and Canada the goiters are usually not large and cretinism is rare. The draft boards of World War I found two endemic goiter areas in the United States, one centering around the Great Lakes region and the other in the Pacific Northwest. However, it is not limited to these areas and may be found in almost any part of this country to some extent. It continues to be a public health problem in the United States.

Because individuals cannot tell whether their natural supply of iodine is adequate, some plan of giving everyone the food equivalent of iodine has been tried in many parts of the globe for many years. The most popular and most practical way has been to add an infinitesimal (0.01 per cent) amount of necessary iodine to table salt.

The name iodized salt came into use more than 25 years ago for table salt containing iodine equivalent in amount to that which would result from adding 0.02 per cent of sodium or potassium iodide to ordinary table salt. About a decade ago it was demonstrated that the addition of small quantities of certain substances would greatly retard the loss of iodine that otherwise occurs in packaged iodized salt. Use of these so-called stabilizers has made it possible to reduce the quantity of iodide from 0.02 to 0.01 per cent of the salt with assurance that the use of such salt will provide an adequate intake of iodine.

The addition of iodide to salt for the prevention of goiter has been impractical in the past in many parts of the world where crude or bulk salt is widely used because of the loss of iodine by vaporization from salt handled in bags or open containers.

Recent studies have shown that the iodate is stable and also effective in the prevention of goiter. It therefore appears that the addition of iodate to salt may be a practical way of preventing goiter in areas where packaging refined salt is not feasible.

The use of iodized salt is the most effective way of combating this important public health problem.



# 12

## NORMAL NUTRITIONAL REQUIREMENTS

Human requirements for the essential nutrients are based on the same physiological considerations the world over and fortunately may be met by an infinite variety of combinations of food and drink. Since the actual requirement of an individual is dependent on physical activity, age, sex, weight, as well as other factors, and would require careful and long study to determine accurately, practical methods of using averages have been devised which serve the very useful purpose of estimating the adequacy of the diets of groups of people. Such information used with a clinical examination and laboratory studies for evidence of malnutrition not only gives an adequate evaluation of the nutritional status but also furnishes the data necessary for planning suitable corrective and preventive measures.

The most complete and valuable table of standards is that prepared by the Food and Nutrition Board of the National Research Council and is given in Table 12-1.

This table is one of recommended allowances. It is not an attempt to set requirements. It is a set of recommended allowances designed to maintain good nutritional status. It is a desirable goal or objective at a level high enough to cover individual variations in the nutritional requirements of normal people.

Although these technical data are essential for accurate calculations and planning, it is necessary to convert the data into meal plans for them to be of practical public health use. This also has been done by the Food and Nutrition Board in three types of menus which suit the usual North American dietary habits. These are:

### MENU 1

#### *Breakfast*

Orange juice  
Cooked cereal—milk  
Eggs  
Toast—butter or fortified margarine  
Beverage

#### *Lunch*

Baked macaroni and tomatoes  
Green beans  
Rolls—butter or fortified margarine  
Fruit in season  
Milk

#### *Dinner*

Broiled chopped steak  
Creamed potatoes—carrots  
Head lettuce—French dressing

Table 12-1. Recommended daily dietary allowances<sup>1</sup> designed for the maintenance of good nutrition of healthy persons in the United States.

(Allowances are considered to apply to persons normally vigorous and living in temperate climate)

	Age Years	Weight kg. (lb.)	Height cm. (in.)	Calories	Protein gm.	Calcium gm.	Iron mg.	Vitamin A I.U.	Thiamine mg.	Ribo- flavin mg.	Niacin mg.	Ascorbic Acid mg.	Vitamin D I.U.
Men .....	25	65 (143)	170 (67)	3200 <sup>2</sup>	65	0.8	12	5000	1.6	1.6	16	75	
	45	65 (143)	170 (67)	2900	65	0.8	12	5000	1.5	1.6	15	75	
	65	65 (143)	170 (67)	2600	65	0.8	12	5000	1.3	1.6	13	75	
Women .....	25	55 (121)	157 (62)	2300 <sup>2</sup>	55	0.8	12	5000	1.2	1.4	12	70	
	45	55 (121)	157 (62)	2100	55	0.8	12	5000	1.1	1.4	11	70	
	65	55 (121)	157 (62)	1800	55	0.8	12	5000	1.0	1.4	10	70	
Pregnant (3rd trimester) Lactating (850 ml. daily)				Add 400	80	1.5	15	6000	1.5	2.0	15	100	400
				Add 1000	100	2.0	15	8000	1.5	2.5	15	150	400
Infants <sup>3</sup> ....	0-1/12 <sup>4</sup>	6 (13)	60 (24)	kg.x120	kg.x3.5 <sup>2</sup>	0.6	6	1500	0.3	0.4	3	30	400
	1/12-3/12	9 (20)	70 (28)	kg.x110	kg.x3.5 <sup>2</sup>	0.8	6	1500	0.4	0.7	4	30	400
	4/12-9/12	10 (22)	75 (30)	kg.x100	kg.x3.5 <sup>2</sup>	1.0	6	1500	0.5	0.9	5	30	400
Children ..	1-3	12 (27)	87 (34)	1200	40	1.0	7	2000	0.6	1.0	6	35	400
	4-6	18 (40)	109 (43)	1600	50	1.0	8	2500	0.8	1.2	8	50	400
	7-9	27 (59)	129 (51)	2000	60	1.0	10	3500	1.0	1.5	10	60	400
Boys .....	10-12	35 (78)	144 (57)	2500	70	1.2	12	4500	1.3	1.8	13	75	400
	13-15	49 (108)	163 (64)	3200	85	1.4	15	5000	1.6	2.1	16	90	400
	16-20	63 (139)	175 (69)	3800	100	1.4	15	5000	1.9	2.5	19	100	400
Girls .....	10-12	36 (79)	144 (57)	2300	70	1.2	12	4500	1.2	1.8	12	75	400
	13-15	49 (108)	160 (63)	2500	80	1.3	15	5000	1.3	2.0	13	80	400
	16-20	54 (120)	162 (64)	2400	75	1.3	15	5000	1.2	1.9	12	80	400

1953 Revision, Food and Nutrition Board, National Research Council.

<sup>1</sup> In planning practical diets, the recommended allowances can be attained with a variety of common foods which will also provide other nutrient requirements less well known; the allowance levels are considered to cover individual variations among normal persons as they live in the United States subjected to ordinary environmental stresses.

<sup>2</sup> These calorie recommendations apply to the degree of activity for the "standard" man and woman described on page 585. For the urban "white-collar" worker they are probably excessive. In any case, the calorie allowance must be adjusted to the actual needs of the individual as required to achieve and maintain his desirable weight.

<sup>3</sup> The recommendations for infants pertain to nutrients derived primarily from cow's milk. If the milk from which the protein is derived is human milk or has been treated to render it more digestible, the allowance may be in the range of 2-3 gm. per kg. There should be no question that human milk is a desirable source of nutrients for infants even though it may not provide the levels recommended for certain nutrients.

<sup>4</sup> During the first month of life, desirable allowances for many nutrients are dependent upon maturation of excretory and endocrine functions. Therefore no specific recommendations are given.



## NORMAL NUTRITIONAL REQUIREMENTS

Bread—butter or fortified margarine  
 Apple pie and cheese  
 Beverage

## MENU 2

*Breakfast*

Tomato juice  
 Ready-to-eat cereal—milk  
 Eggs

Hot biscuits  
 Butter or fortified margarine—jelly  
 Beverage

*Lunch*

Baked sweet potato  
 Turnip greens or collards  
 Sliced onions with vinegar  
 Corn bread or muffins  
 Butter or fortified margarine—molasses  
 Beverage

*Dinner*

Fried fish  
 Hominy grits—cole slaw  
 Bread—butter or fortified margarine  
 Stewed prunes or fruit in season  
 Cookies  
 Beverage

## MENU 3

*Breakfast*

Banana on ready-to-eat cereal  
 Milk  
 Toast—butter or fortified margarine  
 Beverage

*Lunch*

Chick pea soup  
 Tortillas  
 Orange  
 Cocoa or chocolate

*Dinner*

Chili rellenos  
 (Stuffed green peppers)  
 Mexican rice  
 Raw vegetable salad  
 (Cabbage, carrot, green pepper, French dressing)  
 Tortillas  
 Fruit gelatin  
 Milk

An even simpler method of using the same basic data for general educational purposes is to furnish the information in terms of food groups which have been called "The Basic Seven" and are as follows:

- Group 1. Leafy green and yellow vegetables, one or more servings.
- Group 2. Citrus fruits, tomatoes, raw cabbage, one or more servings.
- Group 3. Potatoes and other vegetables and fruits, two or more servings.
- Group 4. Milk and milk products: fluid, evaporated, dried milk or cheese. Children, three to four cups of milk; adults, two or more cups.
- Group 5. Meat, poultry, fish, eggs, dried beans, peas: one to two servings.
- Group 6. Bread, flour, cereals, whole grain, enriched, or restored: daily.
- Group 7. Butter or fortified margarine: daily.

In addition to some foods from each of these groups, the appetite and energy needs may be met by any other foods desired.

In addition to the above recommended dietary allowances, there is a table of minimum requirements for certain nutrients which serve as a legal standard for the enforcement of certain provisions of the Food, Drug, and Cosmetic Act. These standards are set at a minimum level and label statements of quantity are given in terms of fractions of a day's requirement referred to these levels. These figures are given in Table 12-2.

Table 12-2. Minimum daily requirements at various ages for certain vitamins and minerals

	Vitamins					Minerals			
	A	B <sub>1</sub>	B <sub>2</sub>	C	D	Ca	P	Fe	I
	I.U.	Mg.	Mg.	Mg.	U.S.P.U.	Gm.	Gm.	Mg.	Mg.
Infants	1,500	0.25	0.5	10	400	—	—	—	—
Children 1-5 yrs.	3,000	0.50	—	20	400	0.75	0.75	7.5	0.1
6-11 yrs.	3,000	0.75	—	20	400	0.75	0.75	10.0	0.1
12 yrs. or over	4,000	1.0	2.0	30	400	0.75	0.75	10.0	0.1
Adults	4,000	1.0	2.0	30	400	0.75	0.75	10.0	0.1
Pregnancy or lactation	—	—	—	—	—	1.50	1.50	15.0	0.1

Under conditions of food rationing or other situations where the liberal allowances cannot be met it may be necessary to use more restricted rations. Such restrictions must be used with care especially over long periods of time. Undue restrictions are certain to result in difficulties. This question has been studied by both the Food and Nutrition Board of the National Research Council of the United States and the Food and Agriculture Organization of the United Nations. Their conclusions may be summarized as follows:

A semi-starvation diet which will result in a reduced capacity to work, apathy, depression, and increased susceptibility to infectious diseases is one calculated to contain 1,700 calories per day for a man or an average intake of 1,450 calories for a North American or European population of a distribution similar to that of the United States.

A reasonably safe emergency subsistence level is 2,200 calories per man per day or an average intake for the population of 1,900 calories. This is the food consumption level needed to prevent the most serious undernutrition.

A temporary maintenance level designed to maintain fairly good health, but not for rapid or complete rehabilitation is 2,560 calories per man per day, or an average



intake for the population of 2,200 calories. At this level of intake attention should be given to the protein which should be an average of about 60 gm. per person daily, at least 10 per cent of which should be animal protein.

Since many population groups in non-European countries are of smaller size, living in warm climates with less energy output, the recommended calorie intakes may be reduced by 15 to 20 per cent and the protein by 10 per cent.

Table 12-3. Nutritive value of 100 grams of selected foods, edible portion

Food item	Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
<b>MILK, CREAM, ICE CREAM, CHEESE</b>													
<b>Milk:</b>	<i>Percent</i>	<i>Calories</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Milli-grams</i>	<i>Milli-grams</i>	<i>Milli-grams</i>	<i>Inter-national Units</i>	<i>Milli-grams</i>	<i>Milli-grams</i>	<i>Milli-grams</i>	<i>Milli-grams</i>
1. Buttermilk, cultured.....	90.5	35	3.5	0.1	5.1	(118)	(93)	(0.07)	(Trace)	(0.04)	(0.18)	(0.1)	(1)
2. Chocolate flavored <sup>1</sup> .....	83.0	75	3.2	2.2	10.6	109	91	.07	90	.03	.16	.1	0
3. Condensed, sweetened.....	27.0	327	8.1	8.4	54.8	273	228	(.20)	(430)	(.05)	(.39)	(.2)	(1)
4. Dry skim.....	3.5	359	35.6	1.0	52.0	1,300	1,030	.58	(40)	.35	1.96	1.1	7
5. Dry whole.....	3.5	496	25.8	28.7	38.0	949	728	.58	1,400	.30	1.46	.7	6
6. Evaporated, unsweetened.....	73.7	139	7.0	7.9	9.9	243	195	.17	400	.05	.36	.2	1
7. Fresh skim.....	90.5	35	3.5	.1	5.1	(118)	(93)	(.07)	(Trace)	.04	(.18)	(.1)	(1)
8. Fresh whole.....	87.0	69	3.5	3.9	4.9	118	93	.07	(160)	.04	.17	.1	1
<b>Cream; ice cream:</b>													
9. Cream (20 percent); sweet or sour.....	72.5	208	2.9	20.0	4.0	(97)	(77)	(.06)	(830)	(.03)	(.14)	(.1)	(1)
10. Ice cream; plain <sup>1</sup> .....	62.0	210	4.0	12.3	20.8	132	104	.10	540	.04	.19	.1	Trace
<b>Cheese:</b>													
11. Cheddar type.....	39	393	23.9	32.3	1.7	873	610	(.57)	1,740	.04	.50	(.2)	(0)
12. Cottage.....	74.0	101	19.2	.8	4.3	82	263	(.46)	(30)	.02	.29	(.1)	(0)
13. Cream.....	53.3	367	7.1	36.9	1.7	(298)	(208)	(.17)	2,210	(.01)	.14	.1	(0)
14. *Processed; canned <sup>2</sup> .....	37.5	382	21.9	31.8	2.0	716	831	.76	1,260	.03	.43	.1	(0)
15. All other.....	(39)	393	(23.9)	(32.3)	(1.7)	(873)	(610)	(.57)	2,050	.04	.52	.2	(0)
<b>FATS, OILS</b>													
16. *Army spread, canned <sup>3</sup> .....	27.8	562	5.2	56.7	7.7	244	241	.5	2,820	.03	.19	.1	0
17. *Bacon, canned.....	12.6	704	7.9	74	1.6	14	38	.9	(0)	.26	.10	1.5	0
18. Bacon, medium fat.....	20	626	9.1	65	(1.1)	13	108	.8	(0)	(.42)	(.10)	(2.1)	0
19. Butter.....	15.5	733	.6	81	.4	16	16	.2	4 3,300	Trace	.01	.1	0
20. French dressing.....	38.3	423	.8	39	17.3	(5)	(5)	.1	0	0	0	0	0
21. Lard, other shortening.....	0	900	0	100	0	0	0	0	0	(0)	(0)	(0)	0
22. Margarine with vitamin A added.....	15.5	733	.6	81	.4	(2)	(15)	(.2)	5 (1,980)	(0)	(0)	(0)	0

Note: Asterisk indicates Army ration component; parentheses, imputed value.

<sup>1</sup> Calculated from ingredients.<sup>2</sup> Cheddar type.<sup>3</sup> Not less than 56 percent butter fat on dry solids basis, cheese curd, skim milk powder.<sup>4</sup> Year-round average.<sup>5</sup> Plain margarine is considered to have no vitamin A value.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

Food item		Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
		Percent	Calories	Grams	Grams	Grams	Milli- grams	Milli- grams	Milli- grams	Inter- national Units	Milli- grams	Milli- grams	Milli- grams	Milli- grams
23.	Mayonnaise.....	16	720	1.5	78	3.0	(19)	(60)	(1.0)	(210)	(0.04)	(0.04)	(0)	(0)
24.	Solid dressing.....	44.7	391	1.1	36.8	13.9	(9)	(30)	(.4)	(140)	(.02)	(.03)	(0)	(0)
25.	Salad or cooking oil.....	0	900	0	100	0	0	0	0	0	0	0	0	0
26.	Salt pork, fat.....	8	781	3.9	85	0	2	42	.6	(0)	(.18)	(.04)	(.9)	0
EGGS														
27.	Egg yolks, fresh.....	49.4	355	16.3	31.9	.7	147	586	7.2	3,210	.32	.52	.....	0
28.	*Eggs, whole, dried.....	2	593	(48.2)	(43.3)	(2.6)	187	800	8.7	4,460	.35	1.23	.2	0
29.	Eggs, whole, fresh.....	74.0	158	12.8	11.5	.7	54	210	2.7	1,140	.12	.34	.1	0
MEAT, POULTRY, FISH														
Beef:														
30.	Thin—Utility, Grade C: Carcase; side, including kidney fat.....	66	201	18.8	14	0	11	203	2.8	(0)	.12	.15	5.1	0
31.	Medium—Commercial, Grade B: Carcase; side, including kidney fat.....	60	268	17.5	22	0	10	189	2.6	(0)	.11	.14	4.7	0
32.	Carcase trimmed to retail basis.....	63	235	18.2	18	0	11	196	2.7	(0)	.11	.14	4.9	0
33.	*Chopped meat <sup>6</sup> .....	54	325	16.1	29	0	9	174	2.4	(0)	.10	.13	4.4	0
34.	*Roasting meat <sup>6</sup> .....	67	193	18.9	13	0	11	204	2.8	(0)	.12	.15	5.1	0
35.	*Stewing meat <sup>6</sup> .....	63	235	18.2	18	0	11	196	2.7	(0)	.11	.14	4.9	0
36.	Fat—Good, Grade A: Carcase; side, including kidney fat.....	55	317	16.3	28	0	10	176	2.4	(0)	.10	.13	4.4	0
37.	Very fat—Choice, Prime, Grade AA: Carcase; side, including kidney fat.....	47	406	13.7	39	0	8	148	2.1	(0)	.08	.11	3.7	0
	Retail items: <sup>7</sup>													
38.	Chuck roast (wholesale chuck).....	65	218	18.6	16	0	11	200	2.8	(0)	.12	.15	5.0	0
39.	*Corned beef, canned.....	57.3	232	24.4	15	0	29	113	4.0	(0)	.02	.19	2.7	0
40.	*Corned beef, medium.....	54.2	288	15.8	25	0	9	170	2.4	(0)	.05	.10	1.7	0
41.	Dried or chipped.....	47.7	194	34.3	6.3	0	20	370	5.1	(0)	.11	.22	3.7	0

42.	Hamburger.....	55	316	16	28	0	9	172	2.4	(0)	.10	.13	4.3	0
43.	Loin steaks (wholesale loin).....	57	293	16.9	25	0	10	182	2.5	(0)	.10	.13	4.6	0
44.	Rib roast or steak (wholesale rib).....	59	277	17.4	23	0	10	188	2.6	(0)	.11	.14	4.7	0
45.	*Roast, canned.....	60.0	217	25	13	0	9	164	2.2	(0)	.02	.24	4.5	0
46.	Round steak (wholesale round).....	67	194	19.3	13	0	11	208	2.9	(0)	.12	.15	5.2	0
47.	Rump roast (wholesale rump).....	53	341	15.5	31	0	9	167	2.3	(0)	.10	.12	4.2	0
48.	Soup meat (wholesale shanks).....	70	162	20.3	9	0	12	219	3.0	(0)	.13	.16	5.5	0
49.	Stew meat (73 percent lean).....	53	333	15.8	30	0	9	170	2.4	(0)	.10	.12	4.3	0
<b>Lamb:</b>														
Carcass; side:														
50.	Thin.....	66.3	202	17.1	14.8	0	10	184	2.6	(0)	.20	.25	5.6	0
51.	Intermediate.....	55.8	312	15.7	27.7	0	9	169	2.4	(0)	.18	.23	5.2	0
52.	Fat.....	46.2	410	13.0	39.8	0	8	140	2.0	(0)	.15	.19	4.3	0
Retail items, 7 intermediate grade:														
53.	Leg roast (wholesale leg).....	63.7	230	18.0	17.5	0	10	194	2.7	(0)	.21	.26	5.9	0
54.	Shoulder roast (wholesale 3-rib shoulder).....	58.3	290	15.6	25.3	0	9	168	2.3	(0)	.18	.23	5.2	0
55.	Sirloin chop (wholesale leg).....	63.7	230	18.0	17.5	0	10	194	2.7	(0)	.21	.26	5.9	0
<b>Pork:</b>														
Packers' carcass; side:														
56.	Thin.....	50	371	14.1	35	0	8	152	2.1	(0)	.89	.18	3.8	0
57.	Medium.....	43	453	11.9	45	0	7	129	1.8	(0)	.75	.15	3.2	0
58.	Fat.....	35	534	9.8	55	0	6	106	1.5	(0)	.62	.12	2.6	0
59.	Miscellaneous lean cuts <sup>a</sup> .....	52	352	14.5	32.7	0	8	156	2.2	(0)	.92	.18	3.9	0
Retail items: <sup>7</sup>														
Bacon. See Fats, Oils.														
60.	Boston butt.....	60	273	16.6	23	0	10	179	2.5	(0)	1.05	.21	4.5	0
61.	Ham, fresh.....	53	340	15.2	31	0	9	164	2.3	(0)	.96	.19	4.1	0
62.	Ham, smoked.....	42	384	16.9	35	(.8)	10	182	2.5	(0)	.78	.19	3.8	0
63.	Loin.....	58	291	16.4	25	0	10	177	2.5	(0)	1.04	.20	4.4	0
64.	Picnic.....	52	347	14.8	32	0	9	160	2.2	(0)	.94	.18	4.0	0
65.	Pork links; sausage.....	41.9	446	10.8	44.8	0	6	116	1.6	(0)	.22	.15	2.3	0
Salt pork. See Fats, Oils.														
66.	Spareribs.....	53	346	14.6	32	0	8	157	2.2	(0)	.92	.18	3.9	0

NOTE: Asterisk indicates Army ration component; parentheses, imputed value.

<sup>a</sup> Average values for composition of all cuts in a boned and trimmed carcass of commercial grade generally used for (a) chopped meat, (b) roasting and broiling, (c) stewing and boiling.

<sup>7</sup> Values for fresh items are from the medium fat wholesale cuts considered to be nearest approximations for corresponding retail items.

<sup>8</sup> Lean cuts from medium fat carcass weighted according to civilian supply, 1944. Excludes bacon, lard; salt side; fat back.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

Food item	Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
<b>Veal:</b>													
Carcass; side, excluding kidney fat:	Percent	Calories	Grams	Grams	Grams	Milli- grams	Milli- grams	Milli- grams	Inter- national Units	Milli- grams	Milli- grams	Milli- grams	Milli- grams
67. Thin.....	71	151	19.7	8	0	11	212	3.0	(0)	0.18	0.28	6.5	0
68. Medium.....	68	184	19.1	12	0	11	206	2.9	(0)	.17	.27	6.3	0
69. Fat.....	65	218	18.5	16	0	11	199	2.8	(0)	.17	.26	6.1	0
<b>Retail items, 7 medium fat:</b>													
70. Chops (wholesale lean).....	69	176	19.2	11	0	11	207	2.9	(0)	.18	.27	6.3	0
71. Cutlet (wholesale round).....	70	159	19.5	9	0	11	210	2.9	(0)	.18	.28	6.4	0
72. Leg roast or steak (wholesale leg).....	(68)	186	(19.1)	(12.2)	0	11	206	2.9	(0)	.17	.27	6.3	0
73. Stew meat (74 percent lean).....	64	226	18.3	17	0	11	197	2.7	(0)	.17	.26	6.0	0
<b>Variety meats; meat mixtures:</b>													
74. •Beef and gravy, canned 9.....	65.3	188	19.4	11.7	1.3	19	122	2.7	(30)	.09	.19	2.7	0
75. Bologna.....	62.4	217	14.8	15.9	3.6	9	160	2.2	(0)	.31	.30	3.0	0
76. •Chile con carne, without beans, canned 10.....	66.3	198	10.2	14.6	6.4	21	152	.7	160	.01	.10	2.1	0
77. Frankfurters.....	64.3	201	15.2	14.1	3.3	9	164	2.3	(0)	.19	.23	2.4	0
78. •Ham and eggs, canned 11.....	63.9	227	14.4	18.3	1.2	43	166	2.2	500	.16	.24	1.7	0
79. •Hash, cut and beef, canned 12.....	69.4	143	15.1	6.1	7.0	26	(90)	1.3	(0)	.02	.13	2.4	0
80. •Hash, meat and vegetable, canned 13.....	73.3	122	10.0	5.0	9.3	14	(66)	1.2	(0)	.04	.11	2.5	6
81. Heart, fresh.....	75.4	126	(16.5)	(6.3)	(.7)	10	236	6.2	(0)	.54	.90	6.8	14
82. Liver, fresh.....	70.9	131	(19.8)	(4.2)	(3.6)	8	373	12.1	19,200	.27	2.80	16.1	31
83. Liver sausage.....	59.0	258	16.7	29.6	1.5	9	238	5.4	(5,750)	.17	1.12	4.6	(0)
84. •Larders meat, canned 14.....	56.3	270	15.2	22.5	1.7	21	170	1.4	(0)	.29	.21	2.7	0
85. •Pork and gravy, canned 15.....	64.9	206	15.4	15.2	1.9	16	162	1.6	(0)	.19	.24	2.7	0
86. •Pork sausage, beef, canned.....	57.0	280	16.0	24.0	0	17	131	2.2	(0)	.19	.21	2.8	0
87. •Spaghetti with meat, canned 16.....	71.0	142	9.8	3.9	10.2	38	97	1.8	480	.02	.12	2.2	4
88. •Stew, meat and vegetable, canned 17.....	72.9	127	11.6	5.5	7.8	36	(136)	1.4	1,780	.04	.12	2.4	0
89. Tongue, fresh, medium fat.....	68	202	16.4	15	.4	30	119	6.9	(0)	.22	.27	5.0	0
90. •Veena sausage, canned.....	64.1	210	16.0	16.2	0	19	(164)	.6	(0)	.07	.14	3.1	0

# Poultry:

91. Chicken, boned, canned.....	67.1	175	21.8	9.8	0	32	(218)	(1.9)	Trace	.01	.15	3.7
92. Chicken, roasters <sup>18</sup> .....	66.0	194	20.2	12.6	0	16	218	1.9	Trace	.11	.18	8.6
93. Turkey, medium fat <sup>19</sup> .....	58.3	262	20.1	20.2	0	23	320	3.8	Trace	.12	.19	7.9
Fish and shellfish:												
94. Cod.....	82.6	70	16.5	.4	0	18	189	.9	-----	.04	.05	2.3
95. Fish, miscellaneous, medium fat.....	77.2	98	19.0	2.5	0	21	218	1.0	-----	.07	.07	4.2
96. Oysters, solids and liquor.....	87.1	50	6.0	1.2	3.7	68	172	7.1	-----	.18	.23	1.2
97. Salmon, canned.....	67.4	169	20.6	9.6	0	67	286	1.3	19 80	.03	.18	6.5
98. Sardines, canned in oil, drained solids.....	57.4	207	25.7	11.0	1.2	35	365	1.8	290	.06	.12	5.2
99. Sardines, canned in oil, total contents of can.....	47.1	331	21.1	27	1.0	29	299	1.5	710	.05	.10	4.3
100. Shrimp, canned.....	78.3	82	17.8	.8	.8	(75)	(210)	(2.0)	60	.01	.03	1.9
101. Tuna fish, canned, drained solids.....	57.7	217	27.7	11.8	0	34	290	1.7	70	.04	.13	10.6
102. Tuna fish, canned, total contents of can.....	51.4	294	23.9	22.1	0	30	252	1.5	130	.04	.11	9.2

# DRY BEANS AND PEAS, NUTS

## Dry beans and peas:

103.	*Bean soup, navy, dehydrated <sup>20</sup> .....	7.2	332	17.6	1.2	62.7	(148)	(463)	(10.3)	(0)	.46	.22	2.4	1
	Beans, canned, baked.....	71.0	117	5.7	2.0	19.0	(49)	(154)	(3.4)	21 70	.05	.05	.8	21 4
105.	Beans, common or kidney, dry seed.....	10.5	350	22.0	1.5	62.1	148	463	10.3	0	.60	.24	2.1	2
106.	Beans, lima, dry seed.....	12.6	341	20.7	1.3	61.6	68	381	7.5	0	.60	.24	2.1	2
107.	Chickpeas.....	10.6	369	20.8	4.7	60.9	92	375	7.1	Trace	.35	.15	1.4	(2)
108.	Cowpeas.....	10.6	351	22.9	1.4	61.6	80	450	7.8	0	.83	.23	2.2	2
109.	*Pea soup, dehydrated <sup>22</sup> .....	7.2	336	20.4	1.2	60.8	(73)	(397)	(6.0)	220	.62	.21	3.1	2
110.	Peas, split.....	10.0	354	24.5	1.0	61.7	73	397	6.0	370	.87	.29	3.0	2
111.	Soybeans, whole, mature.....	7.5	351	34.9	18.1	23 (12.0)	227	586	8.0	110	1.14	.31	2.1	Trace
	Soy flour; flakes; grits:													
112.	Low fat.....	11	246	44.7	1.1	23 (14.2)	265	623	13.0	70	1.10	.35	2.9	(0)
113.	Medium fat.....	9	283	42.5	6.5	23 (13.6)	244	610	13.0	110	.82	.34	2.6	(0)
114.	Full fat.....	9	375	35.9	20.6	23 (11.4)	195	553	12.1	140	.77	.28	2.2	(0)

NOTE: Asterisk indicates Army ration component; parentheses, imputed value.

<sup>7</sup> Values for fresh items are from the medium fat wholesale cuts considered to be nearest approximations for corresponding retail items.

<sup>8</sup> 90 percent beef, 10 percent tomato gravy.

<sup>10</sup> Not less than 60 percent meat, not more than 8 percent cereals, seasonings.

<sup>11</sup> 50 percent ham, 50 percent whole eggs.

<sup>12</sup> 73 percent beef, 28 percent potatoes.

<sup>13</sup> 50 percent meat, 48 percent potatoes, 2 percent onions.

<sup>14</sup> Pork.

<sup>15</sup> 90 percent pork, 10 percent gravy.

<sup>16</sup> 50 percent meat, 10 percent dry spaghetti, 30 percent tomato puree, 5 percent cheese, 5 percent onions.

<sup>17</sup> 50 percent meat, 15 percent potatoes, 15 percent carrots, 8 percent dry beans, 12 percent tomato puree.

<sup>18</sup> Vitamin values based on muscle meat only.

<sup>19</sup> Based on pink salmon. Canned red salmon may have a value several times higher.

<sup>20</sup> Navy bean meal, farinaceous flour up to 15 percent.

<sup>21</sup> Contributed by tomatoes.

<sup>22</sup> Pea meal, farinaceous flour up to 15 percent.

<sup>23</sup> "Available" carbohydrate.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

Food item	Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
	Percent	Calories	Grams	Grams	Grams	Milli- grams	Milli- grams	Milli- grams	Inter- national Units	Milli- grams	Milli- grams	Milli- grams	Milli- grams
Nuts:													
115. Almonds.....	4.7	640	18.6	54.1	19.6	254	475	4.4	0	0.25	0.67	4.6	Trace
116. Peanut butter.....	1.7	619	26.1	47.8	21.0	74	393	1.9	0	.20	.16	16.2	(0)
117. Peanuts, roasted.....	2.6	600	26.9	44.2	23.6	74	393	1.9	0	24.30	.16	16.2	(0)
118. Pecans.....	3.0	747	9.4	73.0	13.0	74	324	2.4	50	.72	.11	.9	2
119. Walnuts, English.....	3.3	702	15.0	64.4	15.6	83	380	2.1	30	.48	.13	1.2	3
VEGETABLES													
Fresh:													
120. Asparagus.....	93.0	26	2.2	.2	3.9	21	62	.9	1,000	.16	.17	1.2	33
121. Beans, lima, green.....	66.5	131	7.5	.8	23.5	63	158	2.3	280	.25	.14	.9	32
122. Beans, snap.....	88.9	42	2.4	.2	7.7	65	44	1.1	630	.08	.10	.6	19
123. Beet greens.....	90.4	33	2.0	.3	5.6	26	45	3.2	6,700	.05	.17	.3	34
124. Beets.....	87.6	46	1.6	.1	9.6	27	43	1.0	20	.03	.05	.4	10
125. Broccoli.....	89.9	37	3.3	.2	5.5	130	76	1.3	3,500	.09	.21	.9	118
126. Brussels sprouts.....	84.9	58	4.4	.5	8.9	34	78	1.3	400	.11	(.06)	(.3)	94
127. Cabbage.....	92.4	29	1.4	.2	5.3	46	31	.5	80	.07	.06	.3	52
128. Carrots.....	88.2	45	1.2	.3	9.3	39	37	.8	12,000	.07	.08	.5	6
129. Cauliflower.....	91.7	31	2.4	.2	4.9	22	72	1.1	90	.10	.11	.6	69
130. Celery.....	93.7	22	1.3	.2	3.7	50	40	.5	0	.03	.04	.3	7
131. Chard.....	91.8	25	1.4	.2	4.4	26	36	4.0	2,800	.06	.13	.2	38
132. Collards.....	86.6	50	3.9	.6	7.2	249	58	1.6	6,870	.22	(.20)	(.8)	100
133. Corn, sweet, white or yellow.....	73.9	108	3.7	1.2	20.5	9	120	.5	27,390	.15	.14	1.4	12
134. Cucumbers.....	96.1	14	.7	.1	2.7	10	21	.3	230	.04	.09	.2	8
135. Dandelion greens.....	85.8	52	2.7	.7	8.8	187	70	3.1	13,650	.19	.14	(.8)	36
136. Eggplant.....	92.7	28	1.1	.2	5.5	16	37	.4	30	.07	.06	.8	5
137. Kale.....	86.6	50	3.9	.6	7.2	225	62	2.2	7,540	.12	.35	(.8)	115
138. Lettuce, headed.....	94.8	18	1.2	.2	2.9	22	25	.5	540	.06	.07	.2	8

139.	Lettuce, all other.....	94.8	18	1.2	.2	2.9	62	20	1.1	1,620	.06	.07	.2	18
140.	Mustard greens.....	92.2	28	2.3	.3	4.0	220	38	2.9	6,480	.09	.20	.8	102
141.	Okra.....	89.8	39	1.8	.2	7.4	82	62	.7	740	.12	.10	.7	30
142.	Onions, mature.....	87.5	49	1.4	.2	10.3	32	44	.5	50	.03	.02	.1	299
143.	Peanips.....	78.6	83	1.5	.5	18.2	57	80	.7	0	.11	.09	.2	18
144.	Peas, green.....	74.3	101	6.7	.4	17.7	22	122	1.9	680	.36	.18	2.1	26
145.	Peppers, green.....	92.4	29	1.2	.2	5.7	11	25	.4	630	.07	.04	.4	120
146.	Potatoes.....	77.8	85	2.0	.1	19.1	11	56	.7	20	.11	.04	1.2	17
147.	Pumpkin.....	90.5	36	1.2	.2	7.3	21	44	.8	(3,400)	(.05)	(.08)	(.6)	8
148.	Radishes.....	93.6	22	1.2	.1	4.2	37	31	1.0	30	.04	.04	.1	24
149.	Rutabagas.....	89.1	41	1.1	.1	8.9	55	41	.4	330	.06	.06	.5	36
150.	Spinach.....	92.7	25	2.3	.3	3.2	30	55	3.0	9,420	.12	.24	.7	59
151.	Squash, summer.....	95.0	19	.6	.1	3.9	15	15	.4	260	.04	.05	1.1	17
152.	Squash, winter.....	88.6	44	1.5	.3	8.8	19	28	.6	4,960	.05	.08	.6	8
153.	Sweetpotatoes.....	68.5	125	1.8	.7	27.9	30	49	.7	31 7,700	.10	.06	.7	22
154.	Tomatoes.....	94.1	23	1.0	.3	4.0	11	27	.6	1,100	.06	.04	.6	23
155.	Turnip greens.....	89.5	37	2.9	.4	5.4	259	50	2.4	9,540	.10	.56	.8	136
156.	Turnips.....	90.9	35	1.1	.2	7.1	40	34	.5	Trace	.06	.06	.5	28
Canned:														
157.	Asparagus.....	93.6	21	1.6	.3	3.0	20	34	1.0	32 600	.06	.09	.8	15
158.	Beans, lima.....	80.9	72	3.8	.3	13.5	27	73	1.7	130	.03	.05	.5	8
159.	Beans, snap.....	94.0	19	1.0	0	3.8	27	19	1.4	410	.03	.05	.3	4
160.	Beets.....	89.4	39	1.0	0	8.7	15	29	.6	20	.01	.03	.1	5
161.	Carrots.....	92.2	30	.5	.4	6.1	22	24	.6	12,000	.03	.02	.3	2
162.	Corn, white or yellow.....	80.5	77	2.0	.5	16.1	4	51	.5	27 200	.02	.05	.8	5
163.	Peas, green.....	82.3	69	3.4	.4	12.9	25	67	1.8	540	.11	.06	.9	8
164.	Pumpkin.....	90.2	38	1.0	.3	7.9	(20)	(36)	(.7)	3,400	.02	.06	.5	(0)
165.	Sauerkraut.....	93.2	20	1.1	.2	3.4	(46)	(31)	(.5)	Trace	.03	.20	.2	33 13
166.	Spinach.....	92.3	25	2.3	.4	3.0	34	33	1.6	6,790	.02	.08	.3	14

NOTE: Asterisk indicates Army ration component; parentheses, imputed value.

24 Based on peanuts without skins; when skins are included the thiamine value is higher.

25 118 mg.; may not be available because of presence of oxalic acid.

26 105 mg.; may not be available because of presence of oxalic acid.

27 Based on yellow corn; white corn contains only a trace.

28 Based on pared cucumber; unpared contains about 260 I. U. vitamin A per 100 gm.

29 Green bunching onions contain about 23 mg. ascorbic acid per 100 gm.

30 81 mg.; may not be available because of presence of oxalic acid.

31 If pale varieties only were used, value would be very much lower.

32 Based on green products; bleached products contain only a trace.

33 Drained solids only.

34 90 mg.; may not be available because of presence of oxalic acid.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

Food item	Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
<b>Canned—Continued:</b>													
	Percent	Calories	Grams	Grams	Grams	Milli- grams	Milli- grams	Milli- grams	Inter- national Units (1,880)	Milli- grams	Milli- grams	Milli- grams	Milli- grams
167. Tomato catsup .....	69.5	110	2.0	0.4	24.5	12	18	0.8	(1,880)	0.09	0.07	2.2	11
168. Tomato juice .....	93.5	23	1.0	.2	4.3	(7)	(15)	(.4)	1,050	.05	.03	.7	16
169. Tomato puree .....	89.2	40	1.8	.5	7.2	(11)	(37)	(1.1)	1,880	.09	(.07)	1.8	28
170. Tomatoes .....	94.2	21	1.0	.2	3.9	(11)	(27)	(.6)	1,050	.05	.03	.7	16
<b>Dehydrated: 35</b>													
171. *Cabbage, unsulfited 36 .....	8.8	346	13.7	1.8	68.8	374	274	4.7	520	.41	.37	2.4	189
172. *Carrots .....	5.6	361	4.0	1.4	83.1	(242)	(102)	(5.9)	117,000	.29	.23	3.2	11
173. *Onions .....	9.9	350	10.1	1.0	75.2	158	266	3.1	20	.23	.15	1.1	37
174. *Potatoes .....	7.2	363	7.1	.7	82.0	25	103	3.7	(0)	.25	.10	4.8	26
175. *Sweetpotatoes .....	5.3	373	5.1	.9	86.1	(76)	(75)	(2.3)	21,900	.18	.14	1.9	34
<b>FRUIT</b>													
<b>Fresh:</b>													
176. Apples .....	84.1	64	.3	.4	14.9	6	10	.3	90	.04	.02	.2	5
177. Apricots .....	85.4	56	1.0	.1	12.9	16	23	.5	2,790	.03	.04	.7	4
178. Avocados .....	85.4	265	1.7	26.4	5.1	10	38	.6	280	.12	.15	1.1	16
179. Bananas .....	74.8	99	1.2	.2	23	8	28	.6	430	.09	.06	.6	10
<b>Berries:</b>													
180. Blueberries .....	83.4	68	.6	.6	15.1	16	13	.8	280	(.03)	(.07)	(.3)	16
181. Strawberries .....	90.0	41	.8	.6	8.1	28	27	.8	60	.03	.07	.3	60
182. Other berries .....	84.4	65	1.2	.8	13.2	36	34	.9	320	.03	(.07)	(.3)	23
183. Cantaloupe .....	94.0	23	.6	.2	4.6	17	16	.4	373,420	.06	.04	.8	33
184. Grapefruit .....	88.8	44	.5	.2	10.1	17	18	.3	Trace	.04	.02	.2	40
185. Grapes .....	81.6	74	.8	.4	16.7	17	21	.6	80	.05	.03	.4	4
186. Lemons .....	89.3	44	.9	.6	8.7	(14)	(10)	(.1)	0	.04	Trace	.1	45
187. Limes .....	86.0	53	.8	.1	12.3	(14)	(10)	(.1)	0	(.04)	(Trace)	(.1)	27
188. Oranges .....	87.2	50	.9	.2	11.2	33	23	.4	(190)	.08	.03	.2	49
189. Peaches .....	86.9	51	.5	.1	12.0	8	22	.6	880	.02	.05	.9	8

190.	Pears.....	82.7	70	.7	.4	15.8	13	16	.3	20	.02	.04	.1	4.
191.	Pineapples.....	85.3	58	.4	.2	13.7	16	11	.3	130	.08	(.02)	(.2)	24
192.	Plums.....	85.7	56	.7	.2	12.9	17	20	.5	350	.15	(.03)	.6	5
193.	Rhubarb.....	94.9	18	.5	.1	3.8	38	25	.5	30	.01	-----	.1	9
194.	Tangerines; other mandarin type oranges.....	87.3	50	.8	.3	10.9	(33)	(23)	(.4)	(420)	.07	(.03)	(.2)	31
195.	Watermelons.....	92.1	31	.5	.2	6.9	7	12	.2	590	.05	.05	.2	6
<b>Canned:</b>														
196.	Apples; applesauce.....	79.8	80	.2	.1	19.7	(4)	(6)	(.2)	(60)	.01	.01	Trace	1
197.	Apricots.....	77.3	89	.6	.1	21.4	(10)	(15)	(.3)	1,350	.02	.02	.3	4
198.	Cherries.....	78.1	86	.6	.1	20.8	(11)	(14)	(.3)	(430)	.03	.02	.2	3
199.	Cranberry sauce.....	48.1	209	.1	.3	51.4	(8)	(7)	(.3)	(30)	-----	(.04)	-----	2
200.	Fruit cocktail.....	(80.6)	78	(.4)	(.2)	(18.6)	(9)	(12)	(.4)	160	.01	.01	.4	2
201.	Grapefruit juice.....	89.4	41	.5	.2	9.4	8	12	.4	Trace	.03	.02	.2	35
202.	Grapefruit segments.....	79.8	81	.6	.2	19.1	13	14	.3	Trace	.03	.02	.2	30
203.	Orange juice.....	86	55	.6	.1	12.9	(33)	(23)	(.4)	(100)	.07	.02	.2	42
204.	Peaches.....	80.9	75	.4	.1	18.2	(5)	(14)	(.4)	450	.01	.02	.7	4
205.	Pears.....	81.1	75	.2	.1	18.4	(8)	(10)	(.2)	Trace	.01	.02	.1	2
206.	Pineapple juice.....	86.2	54	.3	.1	13.0	15	8	.5	80	.05	.02	.2	9
207.	Pineapples.....	78.0	87	.4	.1	21.1	29	7	.6	80	.07	.02	.2	9
208.	Plums; Italian prunes.....	78.6	84	.4	.1	20.4	8	12	1.1	(230)	.03	.03	.4	1
<b>Dried:</b>														
209.	*Apple nuggets.....	1.6	380	1.4	1.0	93.9	24	42	4.1	(0)	.05	.08	.5	11
210.	Apricots <sup>39</sup> .....	24	292	5.2	.4	66.9	86	119	4.9	7,430	.01	.16	3.3	12
211.	*Cranberries.....	4.9	409	2.9	6.6	84.4	82	22	3.4	660	.19	.18	.9	33
212.	Peaches <sup>39</sup> .....	24	295	3.0	.6	69.4	44	126	6.9	3,250	.01	.20	5.4	19
213.	Prunes <sup>40</sup> .....	24	299	2.3	.6	71.0	54	85	3.9	1,890	.10	.16	1.7	3
214.	Raisins <sup>40</sup> .....	24	298	2.3	.5	71.2	78	129	3.3	50	.15	.08	.5	Trace
<b>Synthetic fruit powders, canned:</b>														
215.	*Grape juice <sup>41</sup> .....	.2	42 260	.1	.5	3.1	132	65	.1	(0)	0	(0)	(0)	600
216.	*Lemon juice <sup>43</sup> .....	1.7	42 336	.4	.3	60.6	60	33	1.5	(0)	(0)	(0)	(0)	876
217.	*Orange juice <sup>44</sup> .....	1.9	42 341	1.1	.2	65.1	180	101	2.2	(0)	(0)	(0)	(0)	927

Note: Asterisk indicates Army ration component; parentheses, imputed value.

<sup>35</sup> Freshly dehydrated products; some loss of vitamins is to be expected during storage.

<sup>36</sup> If sulfited, the thiamine value would be much lower, and the ascorbic acid value would be about double.

<sup>37</sup> Based on deeply colored varieties.

<sup>38</sup> 51 mg.; may not be available because of presence of oxalic acid.

<sup>39</sup> Sulfured.

<sup>40</sup> Unsulfured.

<sup>41</sup> Citric acid, dextrose, coloring, flavoring, ascorbic acid.

<sup>42</sup> Caloric value of organic acids included.

<sup>43</sup> Powdered lemon juice and corn sirup, dextrose, citric acid, oil of lemon, ascorbic acid.

<sup>44</sup> Powdered orange juice, lemon juice, and corn sirup, dextrose, citric acid, oil of orange, ascorbic acid.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

Food item		Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
<b>GRAIN PRODUCTS</b>														
<b>Flour, meal:</b>														
<i>Corn meal:</i>														
218	White, degerminated.....	Percent	Calories	Grams	Grams	Grams	Milli-grams	Milli-grams	Milli-grams	Inter-national Units	Milli-grams	Milli-grams	Milli-grams	Milli-grams
219	White, whole-grain.....	12	355	7.5	1.1	78.8	10	140	1.0	(0)	0.16	0.09	0.9	0
220	White, whole-grain.....	12	365	9.1	3.7	73.9	18	248	2.7	(0)	.41	.12	1.7	0
220	Yellow, degerminated.....	12	366	8.3	1.2	78.0	10	140	1.0	300	.15	.06	.9	0
221	Yellow, whole-grain.....	12	365	9.1	3.7	73.9	18	276	2.7	510	.45	.17	2.1	0
222	Cornstarch.....	12	352	.5	.2	87.0	Trace	Trace	Trace	(0)	(0)	(0)	(0)	0
<b>Flour:</b>														
223	Buckwheat, light.....	12	354	6.3	1.1	79.7	11	88	1.0	(0)	45.31	45.08	462.1	0
224	Rye, light.....	11	358	8.9	.9	78.5	18	278	1.3	(0)	.15	.07	.9	0
225	Rye, whole-grain.....	10	361	11.2	1.7	75.2	61	369	4.8	(0)	.47	.21	1.7	0
<b>Soy. See Dry Beans and Peas.</b>														
226	Wheat, patent.....	12	355	10.8	.9	75.9	19	93	.7	(0)	.07	.03	.8	0
227	Wheat, patent, enriched.....	12	355	10.8	.9	75.9	19	93	(2.9)	(0)	(.44)	(.26)	(3.5)	0
228	Wheat, self-rising.....	12	340	10.2	.9	72.9	220	330	.6	(0)	.02	.02	.7	0
229	Wheat, self-rising, enriched.....	12	340	10.2	.9	72.9	220	330	(2.9)	(0)	(.44)	(.26)	(3.5)	0
230	Whole wheat.....	11	360	13.0	2.0	72.4	38	385	3.8	(0)	.56	.12	5.6	0
<b>Baked goods:</b>														
<b>Bread:</b>														
231	Rye, light.....	37.6	263	(6.4)	(3.4)	(51.7)	(22)	(96)	(.8)	(0)	.16	(.04)	(1.1)	0
232	White, enriched.....	35.9	261	8.5	2.0	52.3	(56)	(100)	(1.8)	(0)	(.24)	(.15)	(2.2)	0
233	Whole wheat.....	37	262	9.5	3.5	48.0	(60)	370	2.6	(0)	.28	.15	3.5	0
234	Cake, light batter type.....	26.8	327	6.4	8.2	57.0	62	(126)	2.0	(0)	.03	.10	.7	0
235	Cookies, assorted, plain.....	4.8	438	6.0	12.7	75.0	(22)	(65)	(.6)	(0)	(.04)	(.04)	(.5)	0
236	Crackers, assorted, assorted.....	4.5	422	9.5	10.3	72.7	22	102	1.5	(0)	(.07)	(0)	(.6)	0
237	Crackers, graham.....	5.5	419	8.0	10.0	74.3	20	203	1.9	(0)	.30	.12	1.5	0
238	Fig bars.....	13.8	363	4.2	4.8	75.8	(69)	(69)	(1.3)	(0)	(.02)	(.06)	(.9)	0
239	Pie, apple.....		266	(2.9)	(9.6)	(42.0)	(11)	(22)	1.9	(0)	(.06)	(.04)	.4	(0)
240	Pie, cream.....		223	(2.8)	(9.8)	(31.0)	20	(38)	.5	(0)	.03	.08	.2	(0)
241	Rolls, plain, enriched.....	29.4	304	8.2	6.1	54.1	(56)	(100)	(1.8)	(0)	(.24)	(.15)	(2.2)	0
242	Rolls, sweet, unenriched.....	29.6	304	7.8	5.4	56.0	(56)	(100)	.5	(0)	.08	.13	.8	0

Breakfast cereals:														
243.	Corn flakes.....	9.3	359	7.9	.7	80.3	(10)	56	(1.0)	(0)	(.116)	.08	1.6	0
	Corn flakes, restored. See page 4.													
244.	Oatmeal.....	8.3	396	14.2	7.4	68.2	54	365	5.2	(0)	.55	.14	1.1	0
245.	Rice flakes; puffed rice.....	8.8	363	7.2	.4	82.6	(9)	(92)	.9	(0)	(.06)	(.03)	(1.4)	0
	Rice flakes; puffed rice, restored. See page 4.													
Wheat cereals:														
246.	Farina.....	11	359	11.5	1.0	76.1	21	125	.8	(0)	.06	.06	1.0	0
247.	Farina, enriched.....	11	359	11.5	1.0	76.1	21	125	(1.3)	(0)	(.37)	(.26)	(1.3)	0
248.	Flakes; puffed wheat.....	6.2	372	11.9	1.5	77.7	33	353	3.7	(0)	.15	.12	4.2	0
	Flakes; puffed wheat, restored. See page 4.													
249.	Shredded wheat.....	7.7	369	10.4	1.4	78.7	(38)	(385)	(3.8)	(0)	.20	.14	4.2	0
250.	Whole-grain, uncooked.....	8.7	368	11.7	2.0	75.8	38	385	3.8	(0)	.45	.13	4.6	0
Other cereals:														
251.	Barley, pearled, light.....	11.1	357	8.2	1.0	78.8	16	189	(2.0)	(0)	.12	.08	3.1	0
252.	Hominy.....	11.4	357	8.5	.8	78.9	11	70	1.0	(0)	.15	.05	(.9)	0
253.	Macaroni; spaghetti.....	11	360	13	1.4	73.9	22	144	1.2	(0)	.13	.08	2.1	0
254.	Noodles.....	9.1	385	14.3	5.0	70.6	24	156	1.9	(200)	(.13)	(.12)	(2.1)	0
Rice:														
255.	Brown.....	12.0	356	7.5	1.7	77.7	39	308	5.5	(0)	.29	.05	4.6	0
256.	Converted.....	(12.3)	351	(7.6)	(.3)	(79.4)	(9)	(92)	(.7)	(0)	.23	.04	3.8	0
257.	White.....	12.3	351	7.6	.3	79.4	9	92	.7	(0)	.05	.03	1.4	0
258.	Tapioca.....	12.6	350	.6	.2	86.4	12	12	(1.0)	(0)	0	(0)	(0)	0
SUGARS, SWEETS														
259.	Honey.....	20	319	.3	0	79.5	5	16	.9	(0)	Trace	.04	.2	4
260.	Jams; marmalades.....	28	288	.5	.3	70.8	12	12	(.3)	10	.02	.02	.2	6
261.	Jellies.....	34.5	261	.2	0	65.0	(12)	(12)	(.3)	(10)	(.02)	(.02)	(.2)	4
262.	Molasses, cane.....	24	240	(0)	(0)	(60)	273	51	6.7	(0)	.08	.16	2.8	(0)
263.	Sirup, table blends.....	25	296	(0)	(0)	(74)	46	16	4.1	0	0	.01	.1	(0)
264.	Sugar, brown.....	3	382	(0)	(0)	(95.5)	46 76	46 37	2.6	(0)	(0)	(0)	(0)	(0)
265.	Sugar, granulated or powdered.....	.5	398	(0)	(0)	99.5	(0)	(0)	.1	(0)	(0)	(0)	(0)	0

<sup>46</sup> Based on dark brown sugar; lower values for light brown sugar.

Note: Asterisk indicates Army ration component; parentheses, imputed value.

<sup>45</sup> Whole-grain buckwheat flour has approximately 0.61 mg. thiamine; 0.16 mg. riboflavin; and 1.2 mg. niacin per 100 gm.



Table 12-3 (cont.). Nutritive value of 100 grams of selected foods, edible portion

	Water	Food energy	Protein	Fat	Carbo- hydrate	Calcium	Phos- phorus	Iron	Vitamin A value	Thiamine	Ribo- flavin	Niacin	Ascorbic acid
	Percent	Calories	Grams	Grams	Grams	Milli- grams	Milli- grams	Milli- grams	Inter- national Units	Milli- grams	Milli- grams	Milli- grams	Milli- grams
266. *Barley, hulls	(3)	259	17.7	0	47.0	40	510	9.2	(0)	0.03	0.83	47.6	(0)
267. Chickadee, assayed	2.3	570	(5.5)	52.9	(18)	48	343	2.5	(0)	Trace	.24	1.1	(0)
268. Cocoa	4.3	329	(9.0)	18.8	(31.0)	49	709	2.7	(0)	Trace	(.39)	(2.3)	(0)
269. Coconut, dry, shredded	3.3	579	3.6	39.1	53.2	43	191	3.6	0	Trace	Trace	Trace	(0)
270. Gelatin dessert powder	1.6	392	9.4	0	88.7	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
271. Olives, green	75.2	144	1.5	13.5	4.0	101	15	2.0	420	Trace	Trace	Trace	7
272. Peas, green	65.2	11	.5	.2	1.9	24	22	.9	190	.01	.02	Trace	(0)
273. Wheat germ	11.0	389	25.2	10.0	49.5	84	1,096	8.1	(0)	2.05	.80	4.6	(0)
274. Yeast, compressed, baker's	70.9	109	13.3	.4	13.0	25	605	4.9	(0)	.45	2.07	28.2	(0)
275. Yeast, dried, brewer's	7.0	348	46.1	1.6	37.4	106	1,893	18.2	(0)	9.69	5.45	36.2	(0)

NOTE: Asterisk indicates Army ration component; parentheses, imputed value.

48 95 mg.; may not be available because of presence of oxalic acid.  
49 160 mg.; may not be available because of presence of oxalic acid.

47 Based on vegetable extract type; meat extract type may have up to 27.0 mg. of niacin per 100 gm.

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# 13

## NUTRITION IN PREVENTIVE MEDICINE

The first recognition of the public health importance of food in this country was in relation to problems of sanitation and adulteration. The first federal action in this field was the authority given the Public Health Service in 1893 to establish sanitary regulations for common carriers in interstate traffic. The first state laws governing contamination or adulteration of food were passed in 1880 to 1889 in four states. The Federal Food and Drug Act was passed in 1906 and expanded in the Food, Drug and Cosmetic Act of 1938. Milk sanitation standards were first set by the Public Health Service in 1924.

The work of Goldberger and his associates in the Public Health Service on the dietary cause of pellagra in the southern United States demonstrated the public health importance of malnutrition and added a new public health responsibility to the earlier work which had been limited to sanitation and adulteration.

The development of pediatrics and the growing knowledge of the elements of nutrition and their effect on the growth and development of children led to early recognition of the great importance of nutrition to child health and the child hygiene divisions of health departments opened the way for the development of nutrition services in state health departments. Our present knowledge of the tremendous importance of good nutrition in the maintenance of the best degree of health and our extensive knowledge of the numerous nutritive essentials and the element of a good diet require that the present-day health department deal adequately with this new field of preventive medicine.

This problem of adequate nutrition is so different from other health problems that it requires a new approach by the health officer. It is vast in its ramifications, involving as it does such diverse problems as crop production programs, farm machinery and manpower, food distribution and rationing, food preservation, processing and transportation, storage and proper food preparation, as well as nutrition education, and the diagnosis, prevention, and treatment of specific dietary deficiency diseases. It is obvious that such problems cannot be solved by any one agency alone. Close cooperation and intimate relations among a number of agencies, of which one certainly should be the health department, are essential.

Some of the lines along which a state health department nutrition program might operate are as follows:

1. Conduct appraisals of nutritional status. Even small samplings are of value in indicating the need for more comprehensive appraisals. The determination of the prevalence of nutritional diseases is as much a health department function as the determination of the prevalence of infectious diseases. Such appraisal is made preferably by a combination of dietary survey, clinical survey, and laboratory determina-



tions. The dietary survey may be conducted by a variety of methods. The general technic is an inquiry into the food consumed over a given period of time and the calculated nutritive value compared with a standard of intake such as the recommended allowances of the Food and Nutrition Board. The value of such surveys depends on the training of the surveyor and the care with which the data are collected and analyzed. This type of data gives an excellent indication of food habits, trends in consumption and a background for further study of the prevalence of deficiency symptoms. Although valuable in itself, the dietary survey becomes of greater value when combined with a clinical study of the prevalence of symptoms of malnutrition. This requires the services of a physician trained in the recognition of the skin, mouth, tongue, eye, and neurological lesions of mild deficiency states and the value of the clinical study is enhanced if laboratory data can be added.

2. A nutrition appraisal furnishes a sound foundation for a specific nutrition program. From this base the health officer can proceed with confidence to attack the problem in a variety of ways. He can make specific recommendations in regard to school lunch programs and nutrition education in the school. His program of nutrition education and consultative work with individuals, families, and other agencies interested in nutrition work is a most important function. His information service should prepare nutrition and health material related to other nutrition material available in the state. This should be handled as a part of the health education program.

3. An important field of direct service is that of adequate nutrition for inmates of institutions such as prisons, sanatoria, homes for the aged, orphanages and children's camps. The health department nutritionist can do much in this field to obtain adequate nutrition at lower cost and give better protection against food and water-borne diseases.

Other fields of direct service are an industrial nutrition service and the enforcement of regulations dealing with food handling, adulteration and sanitation.

4. A most important nutrition function for the health officer is that of leadership in policy making and program planning. It is essential that there be collaboration between the many public, private, and civic agencies with an interest in nutrition. Many agricultural, welfare, relief, and other agencies have had good nutrition programs for many years. The health officer should help coordinate these activities to secure the best results in the health field.

5. Staff education in nutrition and aid to local health departments require the services of trained nutritionists.

6. Finally, constant study, investigation, and research should always be included to discover better methods, to better the application of existing methods, and constantly to evaluate changing conditions.

## INTERNATIONAL HEALTH AND NUTRITION PROBLEMS

We do not yet know the full extent of malnutrition in the United States nor do we know how much better nutrition might improve our national efficiency and productiveness or reduce our morbidity and mortality statistics.

In planning nutrition programs in relation to health it must be remembered that adequate food production and availability are the basic problems of international

significance. A comprehensive program in the United States requires consideration of the world food situation and nutritional problems in other countries. Three of the United Nations organizations are intimately concerned with nutrition, food, and health. The World Health Organization has malnutrition as one of the great health fields to which it must give attention. A nutrition division of this organization has started work on kwashiorkor and goiter, and of great health significance is the Nutrition Institute of Central America and Panama set up under the Pan-American Sanitary Bureau. This institute has begun an active program not only of research but to furnish training, analyses, advice, and assistance to its member countries in attacking nutritional problems.

Another very important international nutrition service is that of the Food and Agriculture Organization. The principal problems of this organization are those of agricultural production and distribution. However, its nutrition division carries out an important function in the field of nutrition education, and in relating nutrition and health to agricultural improvement, and in the world movement of food.

The third international organization concerned with nutrition is the United Nations Children's Fund (UNICEF). This organization has played a leading role in milk conservation programs and in the distribution of dried skim milk to needy areas in many parts of the world.

Close cooperation is maintained between the nutrition programs of WHO, FAO and UNICEF. One deals with the nature and prevalence of nutritional diseases, the others with the production and distribution of the agricultural products necessary to control these diseases. Through these and other international efforts, the role of nutrition in health gradually is being established on a world-wide scale and we can see the prospect of a new era of better health comparable to the improvement following the development of sanitation.

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# Section Three

## MAINTENANCE OF HEALTH AND PREVENTION OF DISABILITY

### 14

#### HISTORICAL DEVELOPMENT OF MATERNAL AND CHILD HEALTH

PAUL A. HARPER, M.D., M.P.H.

Maternal and child health is concerned with the physical, mental, and emotional health of pregnant women and of children. One way of defining this field of work is to say that its primary concern is with the preventive aspects of obstetrics and pediatrics and with their application in public health and child welfare. In addition, agencies in this field have provided medical care for certain chronic diseases and handicapping conditions ordinarily included under the term crippled children. This designation, which originally referred to children with orthopedic defects, has gradually been broadened to include children with cerebral palsy, epilepsy, rheumatic fever, congenital defects such as hare lip, and children with handicaps of hearing, speech and vision. A consideration of the historical development of maternal and child health will show that its responsibility has been a continually changing one and that a static definition is not adequate.

The maternal and child health program as we know it today is a development of the past 50 or 75 years. Interest in this area goes back as far as history will take us, but organized programs of the sort currently operating began in France in the late nineteenth century. At this time there was a world-wide concern over the appalling loss of life in early infancy. The French were particularly alarmed about the effect of their low birth rate on their military power, and the question of measures which might improve this manpower situation was debated in the Chamber of Deputies. The names of three French physicians stand out in the early history of this movement: Pierre Budin, Felix Joseph Variot, and Leon Dufour. Budin, one of the famous obstetricians of Paris in the late nineteenth century, initiated the practice of asking the women whom he had delivered to return with their infants after six or more months for a follow-up visit. He was shocked to find how many of these mothers came back without their infants, stating that the child had died during the months since delivery. As a result of this experience, Budin established his "Consultations de Nourrissons" at the Charité Hospital in Paris in 1892. About this same time Variot and Dufour in and near Paris established the forerunners of our present child health conference. These conferences were primarily concerned with the encouragement of breast feeding and the provision of a safe supply of cow's milk for those children whose mothers were unable to feed them from the breast, and the name of these conferences was, appropriately, "Gouttes de Lait." The success of this type of clinic in the saving of life among infants was so great that similar programs

were undertaken in most of the countries of Europe and in the United States and Canada. Physicians in this country who took an interest in this work included Abraham Jacoby, Thomas Morgan Roche, Henry Koplik, L. Emmett Holt, and others. Nathan Strauss established the first of a series of many infant depots in New York City in 1893. Over the next few decades milk depots and clinics were organized by voluntary groups in most large cities in the country. Comparable movements developed in many countries. For example, Dr. Trubie King organized the Plunkett Society in New Zealand, which utilized a group of especially trained nurses and promoted the use of breast milk or, if this failed, gave instruction in the preparation of a safe mixture of cow's milk and otherwise educated mothers in infant care.

Other groups became active. In 1891, Dr. Henry L. Coit and a group of physicians in New Jersey organized the first certified milk commission which cooperated with a few enthusiastic dairymen to improve the conditions of milk production and so assure a safe milk supply. International congresses of interested persons were held in 1905 and 1907. The American Association for the Study and Prevention of Infant Mortality was organized in 1909, was renamed the American Child Hygiene Association in 1918, and was merged with and assumed the name of the American Child Health Association in 1923. These voluntary organizations were effective instruments for the promotion of health services for children. By 1935 it was felt that activities in the interest of child health had been so firmly established that the stimulation of a volunteer privately financed organization was no longer needed and the Child Health Association disbanded.

Reliable figures on infant mortality were one of the greatest needs during the early part of this century. Only a few cities published such information and lack of accurate birth registration decreased the value of even these limited data. For example, some of our most reliable information on infant death rates at the turn of the century was laboriously collected from nine cities by C.-E. A. Winslow and D. F. Holland and between 1880 and 1890 shows a rate of 200 to 300 per 1,000 estimated population under one year of age. More easily available and reliable information was essential if widespread interest and concerted action was to result. This became a process of mutual stimulation between the individuals responsible for our vital statistics and those concerned with child health. More accurate data made clear the serious nature of the situation and created interest in more people who in turn called for better vital statistics. Since 1917, fairly reliable infant mortality rates have been available in the expanding birth registration area; at that time the rate was about 100 per 1,000 live births. Since 1933 data from all the states have been available.

Most of the early work in maternal and child health was the result of efforts such as have been described by voluntary groups and by individuals. The concept slowly grew that the health of mothers and children was a public responsibility and, as such, deserved special status in official health agencies. New York City was the first large political unit in the United States to establish a Bureau of Child Hygiene, in 1908. Dr. Josephine Baker, as the first head of this bureau, gradually overcame great opposition and pioneered in the building of public health programs for children. In 1914, New York became the first state in the union to establish a division of child hygiene in its state health department. This trend toward acceptance of responsibility in this field by official health agencies at state and local level has been



greatly accelerated by federal aid, as will be described. But it should be emphasized that the primary responsibility still remains at the state and local level.

Federal assistance began with the establishment of the United States Children's Bureau in the Department of Commerce and Labor by an Act of Congress in 1912. It was the first government agency of its kind, and was made responsible to undertake research to promote the welfare of infants and children. It was transferred to the newly created Department of Labor in 1913 and was given additional responsibility for the enforcement of child labor laws. Miss Julia C. Lathrop was the first chief. In 1946, the Bureau was again transferred, this time to the Federal Security Agency. In this move the Bureau retained its health and welfare functions but its responsibilities for child labor were left in the Department of Labor.

In 1921, the Infant and Maternity Act (Sheppard-Towner Act) was passed and for the first time federal funds were made available, on a grant-in-aid basis, to assist the various states in developing maternal and child health programs. This law, as is implied by the term "grant-in-aid," required each state to match part of these federal funds with a contribution of its own and also to establish within the state a responsible agency to receive and administer these funds. This gradually resulted in the setting up of an official division or bureau of maternal and child health in each state. These state bureaus have themselves served to stimulate activities in this field and have also acted as a coordinating agency for the activities of many private organizations. There was great controversy as to the wisdom of the Federal Government engaging in such activities, and the opposition became so strong that the Act was allowed to lapse after eight years. A few states provided the necessary funds to continue these activities, but the general effect of withdrawal of federal aid was a considerable decrease in services.

The Social Security Act of 1935 re-established the policy of grants-in-aid to foster maternal and child health work in the various states, and also provided additional funds for a new field of endeavor, crippled children. Funds and activities under this Act have gradually been expanded. The amount of effort and money put into this program by state, local, and voluntary agencies cannot be accurately estimated, but is large.

During World War II, Congress passed the Emergency Maternity and Infant Care Act, better known as EMIC, which provided tax funds to pay for obstetrical care for wives of service men in the lower four pay grades and for pediatric care for the infants of these women. Under this program over 1,100,000 women and their newborn infants were given obstetrical and newborn care, and about 200,000 infants were given additional care during the first year of life. The administration of this Act became the subject of great controversy. It did not always run smoothly and sometimes there was an unnecessary amount of paper work and inflexibility of policy. However, there is no doubt about the value of this activity in raising standards of care and in providing essential services to these mothers and children while their husbands were in the military services (Eliot, 1947; Sinai and Anderson, 1948).

Much of the activity in this field has been the result of cooperative effort between voluntary and governmental agencies and interested individuals. The number of agencies and individuals who have been and are concerned with work in this field is too great for enumeration. But this account would be incomplete if it failed to

recognize that one of the most potent factors in reducing infant and maternal mortality has been the great advances in medical care and particularly the development of the specialties of obstetrics and pediatrics. Obstetrics has long been recognized as a major specialty. The American Board of Obstetrics and Gynecology, Incorporated, was organized in 1930, and now has about 4,500 licentiates. There are probably half as many more physicians well trained in obstetrics.

It is well to recall that pediatrics as a major specialty is a development of less than 50 years. Most of the departments of pediatrics in the various medical schools of the country are less than 35 years old. Yet it is unquestionable that a great deal of the progress in better health for children has been due to the efforts of this specialty group whose reputation depended upon what they accomplished in this particular field. The American Board of Pediatrics was incorporated in 1933 and has now granted certificates to about 5,500 pediatricians. There are probably another 2,500 physicians well trained in pediatrics. The nation-wide survey of Child Health Services and Pediatric Education conducted by the American Academy of Pediatrics in 1946-47 has historical significance which will be discussed in a separate section.

Developments in four other disciplines have already had great influence in this field. The roles of public health nurse, social worker, nutritionist, and therapist have been of continually increasing importance and have led to the use of the team approach. In most clinics the physician and the public health nurse form the nucleus of a group with the social worker and the nutritionist acting as consultants. In larger clinics these latter two workers often become an integral part of the team.

The work of the public health nurse and of therapists is discussed elsewhere.

Social workers are particularly valuable in understanding the patient or client as an individual and as a member of his family and community. They recognize and deal with interpersonal relationships and other social factors as these affect physical and mental health. Their contribution in the problems of adoption, foster care, dependent and chronically ill or convalescent children, unmarried mothers, and other areas can only be mentioned briefly.

Nutritionists have developed a program of applied nutrition which has as its purpose the provision of an adequate diet for mother and child at a minimum of cost. Nutritionists usually function as consultants of public health nurses and physicians but occasionally give direct service to patients in clinics where they analyze diets, make suggestions for improvement or for economy, explain the physician's orders in relation to diet, and aid in the general educational effort.

The series of White House conferences, beginning with one called in 1909 by President Theodore Roosevelt, have had great influence in focusing attention on this work and in guiding the pattern of development. The White House conference in 1930 on Child Health and Protection resulted in the publication of 32 volumes, much of which is still standard in this field. The Mid-Century White House Conference on Children and Youth which was held in December, 1950, was the fifth of the series. This conference took as its purpose the development in children of mental, emotional, and spiritual qualities that will foster a happy childhood and lead to responsible citizenship.

The theme of the 1950 White House conference is significant of a shifting emphasis in maternal and child health work. This field has always been concerned with



the promotion of physical, mental, and social well-being, but as the program for physical health becomes well established, stress is being placed more and more on mental and social health. It is clear that there is no one place to start the task of building mental and social well-being for each individual. To begin with a newborn baby is to neglect the importance of prenatal factors; to work with parents during the prenatal period makes it apparent that some of the problems which arise are related to the infancy and childhood of the parents; to work with children of preschool or school age demonstrates the importance of understanding, cooperative, and sympathetic parents. The approach must be through the many individuals, agencies, and professions that are working for the child and the family. Children must be given the knowledge and incentive with which to seek good health for themselves and in turn for their children; and at the same time parents and prospective parents must be stimulated to promote their own health and that of their children. Such a program must be based on an educative process by which all people may appreciate the meaning of health and desire it sufficiently to work for it.

There is also a changing emphasis with respect to age group. Maternal and child health up to the present has been largely concerned with mothers and preschool children. The problems of children of school age have been less well understood and services for this group have been less well developed. If one may venture a prophecy, it is that the next decades will provide more knowledge of the mental and emotional problems of school age children and particularly of adolescence and that services will develop as knowledge increases.

Increasing cooperation between workers in health and in welfare has been fostered by common problems. For example, the rise of juvenile delinquency is important to all those who are concerned with the health of children and points up the value of joint efforts to understand what forces promote good adjustment and what ones favor maladjustment. The steady rise in adoptions which stems in part from the increase in divorce and in illegitimate birth is another common problem. The increasing number of women who work outside the home brings new questions about day care and health supervision of preschool children.

There is a trend among voluntary agencies toward a categorical approach; this is seen in the rise of important groups interested in and working for children with one kind of handicap. These groups have had great success in organizing parents to improve their own understanding of one particular group of children and in raising funds and promoting legislation for this group. The value of such efforts is great but like other advances it brings new problems for solution.

It is worth repetition to end these brief historical comments with the statement that maternal and child health is a part of the total health program of the community. They are inseparable. Improvement of one benefits the other, and close integration and cooperative action of all individuals and agencies is essential.

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# 15

## MATERNAL HEALTH SERVICES

JOHN WHITRIDGE, JR., M.D.

**Definition.** Obstetrics is defined by Eastman (1950) as "that branch of medicine which deals with parturition, its antecedents and its sequels. It is concerned principally, therefore, with the phenomena and management of pregnancy, labor and puerperium both under normal and abnormal circumstances." The aims of obstetrics, he continues, are that "every pregnancy culminate in a healthy mother and a healthy baby . . . and . . . so to safeguard and ease the whole course [of pregnancy] that both mother and child will conclude the experience in a healthy state both physically and mentally." Maternal health embraces all of the aims and purposes of obstetrics but differs in point of emphasis, in that it is concerned primarily with the ways and means of making available to all women, regardless of race, creed, or economic status, the best that modern obstetrical care can provide. Maternal health, therefore, may be defined as that branch of medical care which has to do with the mobilization of total community resources for the purpose of making available to all in need of it the best possible obstetrical care during the prenatal period, during labor, and following delivery.

As such, maternal health concerns itself with the community standards of prenatal care, of delivery facilities, and of postpartum care. Included, therefore, are the obstetrical ability and training of physicians, the caliber and supervision of midwives, the physical and professional quality of care being furnished in the maternity sections of hospitals, and educational and economic level of the patients themselves, and the degree of coordination attained between the various individuals and groups concerned in rendering obstetrical care. It is of little avail to the unfortunate mother dying of uncontrolled eclampsia in some forlorn hovel that modern obstetrics could probably have prevented the occurrence of this dread complication of pregnancy. Maternal health seeks to answer the question: "Why was this mother not brought under adequate care?" The problem of discovering the cause of eclampsia and newer methods of treatment is left to the science of obstetrics.

**Evaluation of Progress in Maternal Health.** Progress in maternal health can be measured objectively only in terms of mortality rates. It must be understood, however, that mere tabulation of deaths is a grossly unsatisfactory and imperfect mode of assessing the broader aspects of maternal care, since no consideration is given thereby to factors such as permanent or temporary disability or the emotional or mental well-being of mothers. In general, however, it seems justifiable to assume that in those communities where maternal and fetal death rates are low, the quality of obstetrical care being received by patients is of high caliber, and vice versa. The



inadequacy of maternal and fetal death rates in furnishing us with a completely satisfactory picture of maternal health must be granted. Nevertheless, they remain the only objective yardsticks for the measurement of results of maternity care on a local, national, or world-wide basis.

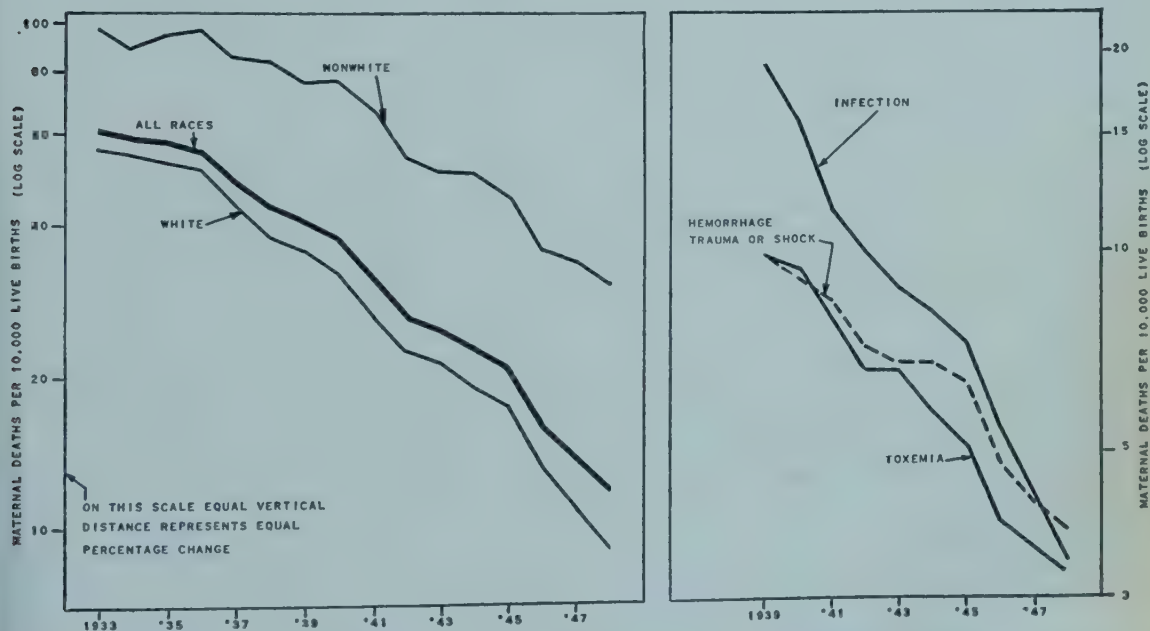
**Maternal Mortality Rates.** Maternal mortality rates are the most commonly used method of assessing the quality and end results of obstetrical care. These rates are expressed in numbers of maternal deaths per unit of births, usually maternal deaths per 1,000 or per 10,000 live births. A more meaningful rate would be obtained were it possible to compare deaths to total pregnancies, but since the registration of live births tends to be more complete than that of either total pregnancies or total births, the ratio of maternal deaths to live births has been adopted by the National Office of Vital Statistics. All rates expressed in the following pages will be in terms of maternal deaths per 10,000 live births in conformity with data compiled by the National Office of Vital Statistics in 1949.

Several important shortcomings should be appreciated in evaluating published maternal mortality rates. Their worth depends upon accurate reporting of all live births and deaths by individual physicians. Many patients undoubtedly die each year of conditions clearly the result of pregnancy or delivery whose deaths are not correctly classified as maternal, because of failure on the part of the attending physician to make any mention of pregnancy or delivery on the certificate of death. Accordingly, recorded maternal mortality rates are somewhat lower than actual rates. This defect, however, is somewhat offset by incomplete reporting of births, but with the present day importance of possessing a birth certificate the percentage of nonreported births is becoming steadily less. Nonetheless, it is of passing interest to note that in 1946 it was estimated that nearly 170,000 live births in the United States were not registered.

An even more important factor in producing errors in maternal mortality rates is the lack of unanimity of opinion relating to the exact definition of a maternal death. In patients succumbing of clearly obstetrical causes such as eclampsia or postpartum hemorrhage, there is no room for disagreement, and deaths of this nature are universally classified as maternal. When pregnancy is associated with conditions such as organic heart disease, tuberculosis, or chronic hypertensive vascular disease, there is considerable divergence in methods of tabulation. For example, a young woman with a severe degree of rheumatic heart disease becomes pregnant and in the latter months of pregnancy decompensates and dies undelivered of cardiac failure. Some favor classifying this as a death due to heart disease and hence nonmaternal, since they can claim quite reasonably that had the patient's heart not been diseased, she would not have died at that time in that fashion. On the other hand, it is well known that pregnancy places a considerable added burden on the heart, and it can be maintained with equal vehemence that if the pregnancy had not existed, death would not have occurred at that time. A reasonable and satisfactory compromise between these conflicting points of view has been reached in some areas by adopting a dual classification, in which deaths from purely obstetrical causes are listed as "maternal deaths," and all other deaths in pregnant or recently delivered women are classified under the heading "deaths associated with pregnancy." By adding the two categories one obtains an index of total deaths associated with pregnancy. This latter figure is a more accurate index of the quality of obstetrical care being ren-

dered, since, as in the case of heart disease associated with pregnancy, the number of fatalities will depend largely on the knowledge and skill of the attending physician, and completeness of care given by him. In assessing progress in maternal health or in comparing one locality with another, the above mentioned differences in interpretation and classification of maternal deaths should be kept in mind. Only through a uniform and clearly understood method of classifying deaths will valid comparisons be possible.

**Causes of Maternal Mortality.** The major terminal causes of maternal deaths are hemorrhage, infection, and the toxemias of pregnancy. These three major types of maternal deaths account for approximately 90 per cent of the total, with the remainder made up of a group of miscellaneous conditions including heart disease, anesthesia accidents, and others not clearly assignable under hemorrhage, infection, or toxemia. The major hemorrhagic conditions leading to fatalities are those associated with abortions, induced or spontaneous; ectopic pregnancy; placenta praevia; abruptio placentae; ruptured uterus; and postpartum hemorrhage. Deaths due to infection include patients with abortions and ectopic pregnancies succumbing terminally of sepsis, and deaths due to sepsis during labor or following viable deliveries. It should be noted that many patients classified under deaths due to infection should more properly be listed as due to hemorrhage, since it frequently happens that bleeding initiates a sequence of events ending terminally in sepsis. Accordingly, national statistics are weighted in favor of infection and correspondingly underestimate the role played by hemorrhage. The toxemias of pregnancy include a group of conditions of obscure etiology characterized by hypertension and albuminuria. Eclampsia is the most treacherous and lethal of these.



Modified from 1947 Chart Book, Children's Bureau, which uses data from National Office of Vital Statistics.

Fig. 15-1. Maternal mortality by race and main causes, United States, 1933 to 1948.

Left, maternal mortality has decreased about 80 per cent since 1933, but the death rate for nonwhite mothers is over 200 per cent greater than the rate for white mothers.

Right, infection has decreased more rapidly than other causes of maternal mortality; and hemorrhage, trauma, or shock has moved into first place in 1948.



In Figure 15-1 may be seen the relative incidence of the three major causes of maternal deaths since 1939. It will be noted that in 1948 hemorrhage for the first time became the leading cause of maternal mortality in the national statistics for the United States. There has been no increase in the absolute number of deaths due to hemorrhage but rather a more rapid decrease in the deaths due to infection. The latter category until 1948 had long been the predominant cause of maternal deaths. There are many and diversified factors influencing the incidence of deaths from these three major causes. Maternal health is more concerned with an analysis of the underlying factors predisposing to maternal deaths than with a discussion of their diagnosis and treatment from the strictly obstetrical viewpoint.

**Maternal Mortality Trend in Recent Years.** During the past two decades there has been a dramatic and gratifying decrease in maternal mortality rates in the United States, a superb achievement of which the medical and nursing profession of this country can be justly proud. In Figure 15-1 may be seen in graphic form a chart of the rates from 1933 through 1948, and it will be noted that during this span of years the rate has been reduced approximately 80 per cent. Expressed in terms of lives this means that had the 1933 rate prevailed in 1948 more than 16,000 additional women would have lost their lives in childbirth in that one year.

A wide variety of circumstances has produced the abrupt decline in maternal mortality noted above. Each of the most important of these will be discussed in some detail from a dual point of view: first, how each factor has operated in the past to produce such magnificent results; second, the steps which remain to be taken to produce even better results in the years ahead.

**The Status of Obstetrical Care Today.** The brilliant achievement in reducing maternal mortality rates described in the preceding section might readily lead one to the conclusion that a state of virtual perfection has been reached. Such a complacent attitude, however, is totally unwarranted. A number of studies of maternal mortality by individuals and by committees of physicians have made clear that approximately two thirds of all maternal deaths can still be considered preventable. By the term preventable is meant that had the patient received ideal care under ideal conditions, her death would probably have been avoided. One of the first studies pointing out this fact was a review of maternal deaths in New York City from 1930 to 1932 (New York Academy of Medicine, 1933). In this analysis a total of 65.8 per cent of 2,041 maternal deaths was considered preventable by a committee of physicians who carefully investigated the events leading up to each and every death. Similarly, Nayar (1950), analyzing 567 maternal deaths in the counties of Maryland from 1937 to 1948, found that the maternal mortality committee had voted 67.0 per cent of these deaths preventable. Other reports have pointed to similar conclusions. One is forced to conclude reluctantly, therefore, that whereas tremendous strides have been made in safeguarding the pregnant woman, the road ahead is still filled with obstacles. Of the 4,122 maternal deaths in the United States in 1948, it is probable that at least 2,700 were unnecessary and could have been avoided if ideal care had been made available.

**Geographic, Racial, and Economic Factors.** Different sections of the United States have for many years rather consistently recorded widely different maternal mortality rates. For example, in 1946 the recorded rate for the east south central section of the country comprised of Kentucky, Alabama, Tennessee, and Missis-

issippi, was 23.6 per 10,000 live births, nearly double the rate of 12.8 per 10,000 live births attained by the New England states. Within these two groups of states even more marked differences occurred. The rate for Connecticut was 9.2 in comparison to 31.4 for Mississippi. Further analysis of data from these two states brings out several factors of importance. Connecticut reported 1,123 nonwhite births, constituting 2.7 per cent of all live births. Mississippi, on the other hand, recorded 31,715 nonwhite births, making up 51.4 per cent of all live births in the state. In Connecticut 98.9 per cent of all births took place in hospitals and 99.9 per cent were attended by physicians. In Mississippi, however, only 38.6 per cent of all births occurred in hospitals and only 63.1 per cent were attended by physicians. Of the 31,715 nonwhite births in Mississippi only 9.6 per cent occurred in hospitals and only 31 per cent were attended by physicians.

While it may be true that certain inherent racial differences exist which may influence mortality associated with childbirth, it would seem apparent from the above that it is not so much a matter of race per se that is important as are facilities for care which are available to a particular group. The basic problem, therefore, becomes an economic one, since, in the less wealthy sections of the country, hospitals are few and are used primarily by the well-to-do. When facilities are limited, the indigent nonwhite goes without. Furthermore, in these areas the ratio of physicians to population is lower. A third factor directly related to economic status is nutrition. Many of the nonwhites are desperately poor, living in hovels, and subsisting on grossly inadequate diets. Many studies have pointed out a relationship between nutritional status and the occurrence of certain complications of pregnancy, particularly the toxemias and the incidence of premature onset of labor. Food habits are usually of many years standing, and one cannot hope to rectify deep-rooted nutritional deficiencies in the short space of a single pregnancy. Dietary intake is unquestionably related to financial status but is also dependent upon the knowledge of what to eat.

All of the above factors are so closely interwoven that it is fruitless to attempt to assign top importance to any single one. It can only be said that on the basis of available evidence poverty, ignorance, lack of access to hospitals and physicians, inadequate diet, poor general hygiene, and poor general state of health often go hand in hand to make pregnancy an unduly hazardous venture. It is often the nonwhite who lives under such conditions.

**Public Health Programs.** In the preceding paragraph attention was called to the startling differences in the quality of maternity care available in various sections of the country. Nearly every portion of the country has communities made up largely of the poor and underprivileged. These groups have in the past contributed, and continue to contribute, a disproportionate number of maternal deaths each year. Even in areas such as the New England states having very low total maternal mortality rates, the nonwhite races furnish a disproportionate number of maternal deaths, nearly two and a half times that of the rate for the white race.

The past two decades have seen a great extension of public health maternity programs designed to make available adequate obstetrical care for those economically or geographically unable to obtain it elsewhere. For the most part these programs have consisted of the establishment of prenatal clinics at strategic points throughout a given area. In some instances the prenatal program has been supple-



mented by home delivery service either through the cooperation of local physicians or the employment of certified nurse midwives.\* Programs such as these under the direction of departments of health have, in many areas, played an important part in providing a much needed service. Further extension of this type of service is urgently needed in those states with higher percentages of nonwhites and large segments of the population bordering on poverty. Even in those states with already established public health maternity programs, renewed effort in the direction of better case finding and improved cooperation between health department and local practicing physicians will lead to better health and happiness for the mothers and infants of their communities.

**Prenatal Care.** One of the first basic advances in obstetrical care in this country came with the acceptance of systematized prenatal care. At the turn of the present century the prevailing custom was for the expectant mother to notify her family physician or midwife of the fact that she was pregnant and to engage him or her to attend her at the onset of labor. Rarely was the patient seen by a physician prior to the onset of labor or the appearance of serious disturbances of the nature of hemorrhage or convulsions. This haphazard practice has been gradually replaced by a system of careful prenatal supervision beginning in the early months of pregnancy. No accurate figures are available on a nation-wide basis concerning the percentage of pregnant women today who receive adequate prenatal supervision. It is highly probable, however, that in excess of 90 per cent of all pregnant women are receiving at last minimal prenatal examinations and supervision.

The essential components of adequate prenatal care are: (1) a careful and complete medical history; (2) a complete physical examination, including internal pelvic mensuration and bimanual pelvic examination to determine the presence or absence of abnormalities of the reproductive tract; (3) urinalysis; (4) blood pressure determination; (5) blood studies, including serological test for syphilis and determination of the Rh factor and hemoglobin level; (6) advice and instruction concerning diet and general hygiene; and (7) a tactful warning about the signs and symptoms of developing abnormalities. Prenatal care which does not include all of the above cannot be considered adequate. Continued education of the public has led to patients knowing about and demanding complete prenatal care.

The initial examination during each pregnancy includes the above and is followed by monthly visits until the thirty-second week, visits every two weeks until the thirty-sixth week, and weekly visits from then until delivery. The minimal required examinations and procedures at each follow-up visit include determination of blood pressure and weight, palpation of the abdomen for position and size of the fetus, auscultation of fetal heart, and urinalysis. The patient is questioned concerning the presence of any abnormal symptoms, particularly headache, visual disturbances, or vaginal bleeding. Further instructions for her general care or diet are given as indicated, and particular attention is paid to the mother's mental and emotional status, and information is given the patient concerning labor and delivery. This routine is considered adequate for normal patients, but the frequency of visits should be greatly increased if there is any evidence of developing abnormalities, particularly toxemia.

\*A certified nurse midwife is a graduate registered nurse who has successfully completed a recognized course in midwifery covering theory and practice.

Prenatal care is being rendered by physicians in their offices, by prenatal clinics attached to hospitals, and by prenatal clinics established and operated by departments of health. In a few remote rural areas an excellent quality of prenatal care is being given by certified nurse-midwives. Irrespective, therefore, of economic status prenatal care has been made available to the overwhelming majority of women in this country. The establishment of free clinics by health departments during the last two decades has done much to make this type of care easily accessible to a group previously deprived of it.

In relation to the major causes of maternal mortality, prenatal care has done more than any other single factor to reduce both the incidence of and mortality from the toxemias of pregnancy. Eclampsia has come to be considered a preventable disease, but its prevention depends upon systematic prenatal follow-up with meticulous attention to, and understanding of, the implications of excessive weight gain, moderate upward blood pressure trends, and the appearance of albuminuria. Other important results of adequate prenatal care have been the early detection and treatment of syphilis in the mother with prevention of the transmission of this disease to the offspring, the detection of Rh iso-immunization, and the discovery of the presence of contracted pelvis. The very core, therefore, of any program of maternity care is the maintenance of adequate prenatal care for the entire community. Only in this way is it possible to detect and make provisions for the proper care of the abnormalities of pregnancy and assure to the mothers of the country the safeguards and advantages of modern obstetrical care.

**Development of Obstetrics as a Specialty.** At the beginning of the present century the specialist in obstetrics was unknown. Deliveries throughout the country were being conducted by untrained midwives and by general practitioners with a minimum of training in the art of obstetrics. During the past 50 years there has been a steady increase in the number of physicians specializing in obstetrics. At the present time there are more than 2,500 physicians certified as competent specialists by the American Board of Obstetrics and Gynecology. There is probably an equal number of thoroughly competent obstetricians who, for one reason or another, have not been inclined to apply for board certification. Assuming that each of these 5,000 competent obstetricians is performing approximately 200 deliveries annually, approximately one million births, one third of the total number, are being conducted by specialists.

Intensive postgraduate training has been necessary to produce each qualified obstetrician. Most of this instruction has been obtained through residences in obstetrics established by teaching hospitals, wherein the young physician spends from three to five years in intensive training in obstetrics and gynecology. These residencies are much sought after by those desiring to complete their training in obstetrics. The organization in 1930 of the American Board of Obstetrics and Gynecology has done much to emphasize the necessity for formal postgraduate training and to encourage young doctors to become fully qualified in their specialty. The problem for the immediate future rests in increasing the number of approved residencies for obstetrical training in order to turn out each year an ever-increasing number of physicians qualified in obstetrics.

**The Role of the General Practitioner.** Although the trend toward specialization has been steady, at least 60 per cent of all births in the United States are still being



attended by general practitioners. The general practitioner today finds himself in an unenviable position. It is quite impossible for any single individual to master all of the basic details of the ever-increasing subdivisions of medical science. He cannot, and should not, be expected to be an expert surgeon, internist, neurologist, pediatrician, gynecologist, and obstetrician, at one and the same time. The average busy general practitioner cannot possibly give the same brand of obstetrical care in complicated cases as the specialist. The general practitioner, therefore, should wherever possible confine himself to the conduct of normal pregnancies, labors, and deliveries, and be willing to refer to the specialist those patients with abnormalities. Ethical teamwork of this nature will lead to the eventual benefit of both types of physicians and more important, to patients. The day of the performance of difficult obstetrical procedures by the partially trained physician is waning, and with its complete disappearance will come even better results to the mothers and children of the country.

**Maternal Mortality Committees.** Reference has been made to the studies of maternal mortality committees and their findings concerning the preventability of maternal deaths. This new and unusual technic of self-appraisal by the medical profession was initiated in the early thirties. These committees, comprised usually of obstetricians, have studied carefully the events pertaining to each and every maternal death in their respective communities. Their frank and unbiased appraisal of the facts has brought into the open many deficiencies existing in community resources for the care of pregnant women. The extent of the influence of such committees cannot be measured on a numerical basis, but it is the opinion of all who have been associated with their activities that, by calling attention to existing deficiencies, they have done much to raise the standards of care being rendered by hospitals and individual physicians.

The first step in the establishment of a maternal mortality committee is the procurement of backing from the appropriate medical society, since it must be emphasized that the venture is a project of self-examination, sponsored and conducted by the medical profession itself. In areas where this type of committee has been in operation for a number of years, the cooperation of practicing physicians has been outstandingly good, and legal implications have been absent. It has been realized that the activities of these committees have been impersonal, and designed for the ultimate benefit of both patients and physicians. There should be no thought of "policing" or retaliatory action against physicians who are judged to have erred.

Notification of a maternal death is obtained from the vital statistics division of the local health department. Upon receipt of this information, contact by one of the committee members is made with the attending physician of the deceased either by personal interview or by letter. All pertinent information is gathered from the physician, from his records, and, with the physician's permission, from the hospital records. At the committee meeting, which often is held in a public gathering open to all members of the medical profession, the facts are presented anonymously and discussed frankly, and several questions are submitted for vote. First, was the death maternal? Second, was it preventable? Third, if preventable, to whom should the responsibility for the death be assigned—the physician, the patient, the hospital, or the community? Often as not the attending physician is present to listen to the discussion of his management of the case. In those areas where information is gathered

by mail and meetings held privately, the physician is informed by letter concerning the committee's opinion of the responsibility for his patient's death together with a brief description of any preferred methods of treatment or diagnosis. The entire project has great educational value both to the members of the committees and the attending physicians.

As previously noted approximately two thirds of all maternal deaths subjected to this type of analysis have been judged to have been preventable. In the majority of instances the physician has been charged with the major responsibility for the fatality while in others the patient has been held largely to blame by failure to seek medical care or to follow instructions. The following phrases have been abstracted from the study of maternal mortality in New York City previously referred to: "ignorance and insufficient training of the attendant prevented him from giving the high quality of care which he was attempting to provide for his patient." "Prenatal care was inadequate and improper." "Physical examination was careless and incomplete." "The high incidence of operative interference during labor was an important factor in the results." "Frequently the operation chosen was the wrong one. Often it was undertaken at an improper time." "The incapacity of the attendants, either in judgment or skill, contributed significantly to the large number of avoidable deaths." "Hospital standards were inadequate in many instances." "The actual physical equipment was inadequate in some hospitals."

Whereas statements of this type may appear at first glance to be blunt, they have been recorded in impersonal fashion. Many physicians have learned never-to-be-forgotten lessons from frank appraisals of this nature. Hospitals have made provisions for prompt transfusion facilities and better nursing care and have established separate maternity sections as the result of having their shortcomings pointed out by maternal mortality committees. These committees have based their findings on the assumption that ideal care should have been available and consequently have done much to influence physicians and hospitals to provide such care. There can be little question but that maternal deaths in every section of the country should be subjected to periodic review by a maternal mortality committee. In those areas in which they are lacking, their organization and operation will do much to improve community maternal health.

**Educational Aspects.** The fundamental basis of past progress in maternal health and of our hopes for further improvement in the years ahead is essentially one of education. This phase of maternal health is by far the most important and at the same time the most challenging. While it is unquestionably true that both physicians and their patients are today better informed concerning good maternity care than ever before, perfection has by no means been attained. The reports of maternal mortality committees or a careful scrutiny of many community-wide resources for the care of pregnant women will reveal certain glaring deficiencies. Patients, either through ignorance or laziness, are failing to seek medical care during pregnancy. In other instances physicians and hospitals are failing to render a satisfactory brand of modern obstetrical care. The basic answer to meeting these two general deficiencies lies in a more intensive educational program directed toward patients and those who are destined to care for patients.

Most women today are familiar with the maxim of early and regular prenatal examination and supervision by a physician. The higher the educational level of



the individual patient, the more is this likely to be true. The great majority of women failing to seek medical attention early in pregnancy come from the ignorant and underprivileged groups. The major task of reaching these offenders falls to the lot of departments of public health and other agencies dealing with indigents or near-indigents. The public health nurse in her daily rounds among her patients plays a role of inestimable value in teaching the importance of early and adequate prenatal care. Simple basic truths have been spread through a community from person to person in this fashion. Great credit must be given to public health nurses for the part they have played in education of the public. In the future ever-increasing efforts of this nature are necessary, particularly in areas where poverty and ignorance abound.

Supplementing the power of the spoken word has been the use of written material. Timely articles in popular publications, books by prominent obstetricians, and pamphlets outlining in simple terms the basic principles of prenatal care and hygiene during pregnancy have been effective in producing a better-informed public. In some instances authors of this type of material have been guilty of distorting the facts somewhat in an effort to be dramatic. Such has been true in regard to the Rh factor and its implications in regard to pregnancy. In general, however, the results of this type of educational program have been eminently beneficial. The present trend toward sex education in high schools and colleges opens an additional avenue for instruction in the hygiene of pregnancy. The incorporation of the basic facts concerning prenatal care in the education of the young women of the country long before marriage and motherhood are contemplated would seem to have great merit. Greater emphasis on the role played by prospective fathers is needed and the education of fathers can likewise begin in high school or college or through the establishment of parents' classes.

As pointed out in the discussion of maternal mortality committees, in most instances the blame for maternal deaths has been assigned to the attending physician or physicians on the basis of incorrect diagnosis or faulty treatment. It can be concluded, therefore, that greater numbers of physicians better qualified in the fundamentals of obstetrical care are needed. Since there has been a tremendous increase in the volume of scientific knowledge to be acquired by medical students, it seems highly improbable that the medical school curriculum can devote more time to the specialty of obstetrics. The obstetrical training of physicians must come in their postgraduate years and should have two clearly recognized goals. The first of these is to create fully qualified obstetrical specialists. The second is to give the physician planning on general practice sufficient obstetrical knowledge to enable him to conduct competently normal pregnancies and deliveries. This fundamental distinction is of importance. In the creation of a qualified specialist a minimum of three years of intensive study is needed. The American Board of Obstetrics and Gynecology requires three years of service in an approved hospital residency in these specialties before a candidate is eligible for certification. In regard to the physician contemplating general practice the ultimate goal differs in that the emphasis should be on the conduct of normal cases, plus sufficient ability and experience for the early recognition of abnormalities. No attempt should be made to train the general practitioner to perform difficult obstetrical procedures. The day of "kitchen table" obstetrics is over.

An additional finding of maternal mortality committees has been a definite failure on the part of attending physicians to seek consultation. Closely integrated with the obstetrical training of general practitioners to recognize deviations from the normal must be emphasis on the value of competent consultation. Lack of easily available consultants, plus an apparent reluctance to seek consultation, have been the major factors at work. Many smaller communities, particularly in rural areas, have no local practicing obstetrician. Several schemes are being tried in various portions of the country to meet this situation. In some localities the larger teaching hospitals are cooperating with smaller hospitals in making readily available a staff of recognized specialists in all of the major branches of medicine. In other areas, health departments have undertaken to furnish consultants to the more remote hospitals and communities. Evidence indicates that in those regions where such plans are in operation the quality of community obstetrical care has improved. Until such time as there is a better distribution of obstetricians, plans of this type are to be desired.

**Place of Delivery.** Until the past few decades hospital care for the pregnant woman was reserved for the poor or the dying. At the beginning of the present century the overwhelming majority of all births took place in the home, and few self-respecting mothers would consider hospitalization for delivery. In various portions of the world with their differing customs and ideas there is still difference of opinion concerning the merits of hospital delivery. Those who contend it is unnecessary and undesirable point out that it is illogical to teach that childbirth is a normal and natural process, only to insist upon hospitalization for delivery. They further emphasize the dangers of cross infection in nurseries and on postpartum wards and state that being at home in familiar surroundings is of great value to the mother's mental attitude. While it must be granted that where competent prenatal care has revealed an entirely normal pregnancy, labor and delivery are usually quite uneventful; nevertheless, sudden and unexpected catastrophies do occasionally occur in the most normal of patients. Foremost of these is the danger of sudden profuse postpartum hemorrhage with its ability to kill rapidly. Second, there is the possibility of the delivery of a severely asphyxiated infant. There can be no question but that the modern maternity unit of a hospital is better equipped to handle these emergencies than would be possible either in the home or by rapid transfer of the patient to a hospital.

Whatever one's personal feelings concerning the advantage or disadvantage of hospital delivery, the trend in the United States has been steadily toward a larger and larger percentage of deliveries in hospitals. In the short space of 12 years, from 1935 to 1947, the percentage of hospital deliveries in this country more than doubled, increasing from less than 40 per cent in 1935 to more than 80 per cent in 1947. The fact that this trend has occurred concomitantly with the rapid decline in maternal mortality is probably more than coincidental, and the majority opinion in this country today is in favor of hospital delivery. Skeptics point out that physicians have urged hospital delivery because it is more "convenient" for them. There can be no denying this fact, but rather than constituting an argument against hospital delivery, it is actually a factor in favor of it. The physician who attempts to give labor and delivery care in homes scattered throughout a community cannot possibly give the same quality of care as when he can group his patients in the



"convenient" environment of a well equipped hospital. He is more rested and able to give more time to his patients.

**Hospital Standards.** In assessing the value of hospital delivery it must be emphasized that the quality of hospital care is of paramount importance. A poorly organized, inefficient hospital maternity service can be more of a hazard than a safeguard to mother and infant. Coincident with the trend toward hospital care for maternity patients has been a steady raising of hospital standards. The studies of maternal mortality committees and the experience of the Emergency Maternal and Infant Care Program during World War II pointed out serious shortcomings in the quality of obstetrical and newborn care as given in many hospitals. Aside from the quality of care, there is the matter of preparing for an added number of patients. Approximately 600,000 women annually are still being delivered in their homes in this country. To prepare for these additional patients and to improve the standard of care already being given is a task of no insignificant magnitude.

In planning for adequate care for maternity patients certain basic considerations are of paramount value. Maternity units should be physically separate areas of hospitals and should have their own nursing staffs. In this way maximum protection against cross infection is afforded both mother and newborn infant. The common use of a single open ward or hospital area by obstetrical, surgical, and medical patients cannot be condoned. Infection still ranks as one of the leading causes of maternal deaths, and penicillin does not excuse the abandonment of time-honored aseptic precautions.

Standards for maternity sections of general hospitals are set forth by the Surgeon General of the U. S. Public Health Service as required by the Hospital and Construction Act. Under these requirements, it is established that there should be one delivery room for every 20 maternity beds and one labor bed for every 10 maternity beds. Eighty square feet of floor space is the minimum per bed in two- or four-bed rooms, with a minimum of 100 square feet of floor space in every one-bed room. It is further recommended that in hospitals of 100 beds or more, the maternity department should be housed in a separate wing or floor.

Labor and delivery room areas should be planned to provide maximum protection for mother and child against sudden unforeseen emergencies. Foremost of these are protection against shock and treatment of severe asphyxia of the newborn. Intravenous fluids, provisions for prompt blood transfusion, provisions for oxygen therapy for both mother and newborn, and standard drugs and equipment to meet all obstetrical emergencies are necessities. With hemorrhage the leading cause of fatalities in parturient women, the establishment of a blood bank assumes primary importance. Smaller hospitals unquestionably find the administration of a blood bank more difficult than do the larger hospitals, since the turnover of blood is less, and the problem of outdated blood becomes more acute. The fact of the difficulty of maintaining a blood bank, however, does not excuse its absence. Blood properly collected and stored can be safely used for 21 days from the date of bleeding. Even the smallest and most remote hospital can with some thought and effort establish a minimal blood bank, perhaps in cooperation with one or more neighboring hospitals. If all else fails, the presence of two or three pints of group O, Rh negative blood will be sufficient for most emergencies and will serve to tide the patient over while donors are being procured. Group O, Rh-negative blood can be safely given

to any recipient without the necessity for cross matching. Whatever the administrative obstacles, the fact remains that provisions for prompt replacement of blood must be given top priority in planning a modern obstetrical unit. Only with blood readily available and an alert physician in attendance will the loss of life from hemorrhage be materially reduced.

Adequate nursing coverage is vital to the efficient operation of maternity units. Patients in labor merit constant attention, particularly when amnesic or analgesic drugs have been administered. In numbers, the nursing staff should be adequate to provide attention to patients in labor, delivery room coverage, and service to postpartum patients without the necessity of obtaining nurses from other portions of the hospital. A competent scrub nurse should be available whenever the physician desires one. There is no more reason why a physician should undertake a difficult delivery without an assistant, than that he should begin a major surgical operation unassisted. Aside from mere numbers the nursing staff should include coverage at all times by at least one nurse who has had extended postgraduate training and experience in obstetrics.

The majority of women in the United States today receive some form of medication for the relief of pain either during labor or for delivery. Each year are recorded a number of deaths due to "accidents of anesthesia." Most of these pathetic catastrophes are preventable and are due to lack of experience on the part of the person administering the drug or agent. For some strange reason it is assumed in some areas that anyone able to hold a can of ether is capable of administering obstetrical anesthesia. It is more difficult, however, to administer competent obstetrical anesthesia than for major surgical procedures since the oxygen requirements of the fetus and the effect of the anesthetic agent upon the fetus must be considered during the process of providing adequate pain relief to the mother. The same thought should be given to the availability of a competent anesthetist for an obstetrical service as for a surgical service.

Organization of the professional staff of hospitals into services is becoming widespread. The pattern being established includes the appointment of a chief of service with authority to set down certain basic rules for the conduct of his service. In obstetrics, staff members are given either full or limited privileges dependent upon their individual training and experience. Staff physicians with limited privileges are usually required to confine their activities to normal and low forceps deliveries. In the event of complications of pregnancy or abnormal labors, they are required to call for assistance from one of the staff members having full obstetrical privileges. This type of staff organization has done much to reduce the incidence of ill-advised traumatic procedures with their accompanying hazard to mother and infant. In many smaller hospitals programs of this nature are handicapped by the fact that there is no fully competent obstetrician on the staff of the hospital. This problem can be met in one of two ways, either by making the best of what is available, or seeking aid from the nearest hospital or community possessing competent obstetricians. The ultimate solution will come only when obstetricians move into the smaller communities. It is to be noted, however, that one of the major factors preventing younger, well-qualified obstetricians from locating in smaller communities in many instances is the unsatisfactory standards of the local hospital. With the steady improvement in hospital standards throughout the country will come a better distribution of physi-



cians of all types between urban and rural areas. At the present time there is an overabundance of competent specialists in the larger cities with a corresponding lack in rural areas and small towns.

**Scientific Advances.** Coincident with the improved obstetrical training of physicians, the acceptance of prenatal care, and the trend toward hospital delivery have come many additions to the tools and technics available to those furnishing care to parturient women. Of major importance among these advances are the sulfonamides, the antibiotics, the freer use of whole blood transfusion, the establishment of blood banks, the advent and increased use of accurate x-ray pelvimetry, better surgical technics, particularly the low cervical caesarean section, and improved technics and safeguards in analgesia and anesthesia. Each of the above has contributed immeasurably to the increased safety of childbirth. With the value of each of these measures well proven it is the duty of every individual charged with the responsibility for the care of pregnant women to be familiar with their use and to see that they are made available when needed.

**The Midwife.** The development of obstetrics as a speciality and the trend to hospital delivery has steadily tended to eliminate the midwife in this country. The number of deliveries performed by nonmedical persons in this country has fallen from 12.5 per cent in 1935 to 5.4 per cent in 1946. It should be noted, however, that the national average of 5.4 per cent is dependent largely on the high percentage of deliveries conducted by midwives in certain southern states with a large number of nonwhite births. To illustrate, in 1946 36.9 per cent of all deliveries and 69.0 per cent of all nonwhite births in Mississippi were attended by nonmedical persons. In contrast, many New England states recorded 0.1 per cent or less deliveries by nonmedical persons. All states recording more than 10 per cent nonmedical deliveries belong to the south and southwest portion of the country where the nonwhite population is high, distances great, facilities for hospitalization meager, and the number of physicians scant.

For the moment, therefore, the midwife must remain in some areas until she can be replaced by physicians and hospitals. In the meantime, much can be done to safeguard the lives of patients who must depend on the midwife for delivery care. Individual states are obtaining legislation to require midwives to secure licenses to practice. Licensure should depend upon the ability to pass an examination on the basic knowledge of obstetrical technics. The legal power to examine and train midwives is usually given to the state health departments and supplemented by the responsibility of supervising their activities. Wherever possible, all patients are examined by a competent physician at least once during pregnancy before being relegated to midwife care. If abnormalities are detected by the physician, every effort is made to obtain medical care for the patient. In this fashion, midwives will be limited in their activities to normal patients. In the event of the development of unforeseen emergencies, the midwife should have ready access to a physician for help and consultation. Only through steps such as these can the lives of patients in the hands of midwives be made reasonably safe. In due time, however, it seems fairly clear that the midwife will fade from the scene in the United States. In countries where physicians and hospitals are totally inadequate, the problem differs considerably in magnitude but basically involves the proper training and supervision of the midwife, plus making medical care available to her patients in emergencies.

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# 16

## INFANT AND PRESCHOOL SERVICES

PAUL A. HARPER, M.D., M.P.H.

**The Problem.** The increasing magnitude of the task of those concerned with child health is shown by Figure 16-1 which gives the rise in the birth rate over

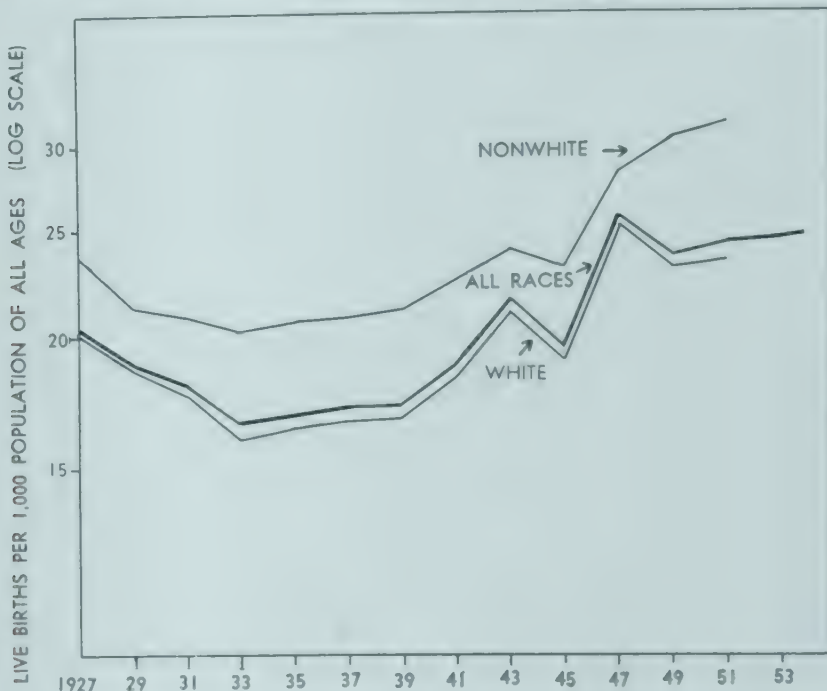


Fig. 16-1. Crude birth rate by race, United States, 1927 to 1954.

The relative rise in birth rate has been greater for the white than for the nonwhite population. Health and education facilities must be provided for about 50 per cent more children each year now than in the 1930-1940 decade.

recent years. The implication of this in the planning of health and education facilities is clear; such facilities must be provided for nearly 50 per cent more children each year now than in the 1930-1940 decade.

Figure 16-2 shows infant mortality by race and by main cause, given as deaths per 1,000 live births. Race, economic status, and geographical location each affect these curves; the influence of race is shown. How much of this difference is biological and how much is due to economic status and geographic location is not established. The lower economic and the rural groups both have higher mortality rates than the higher economic and the urban segments of the population.

These mortality curves have been steadily decreasing for the past 50 years and it seems probable that we shall in the near future reach a point where further decreases, at least for the white race, will be more and more difficult to achieve. The first implication of this fact is that there will be a need—indeed, there is already a need—to develop other indices than mortality curves to give us an adequate measure of progress. This problem becomes more apparent when the wide range in infant mortality in the various reporting areas of the country is considered; thus, states

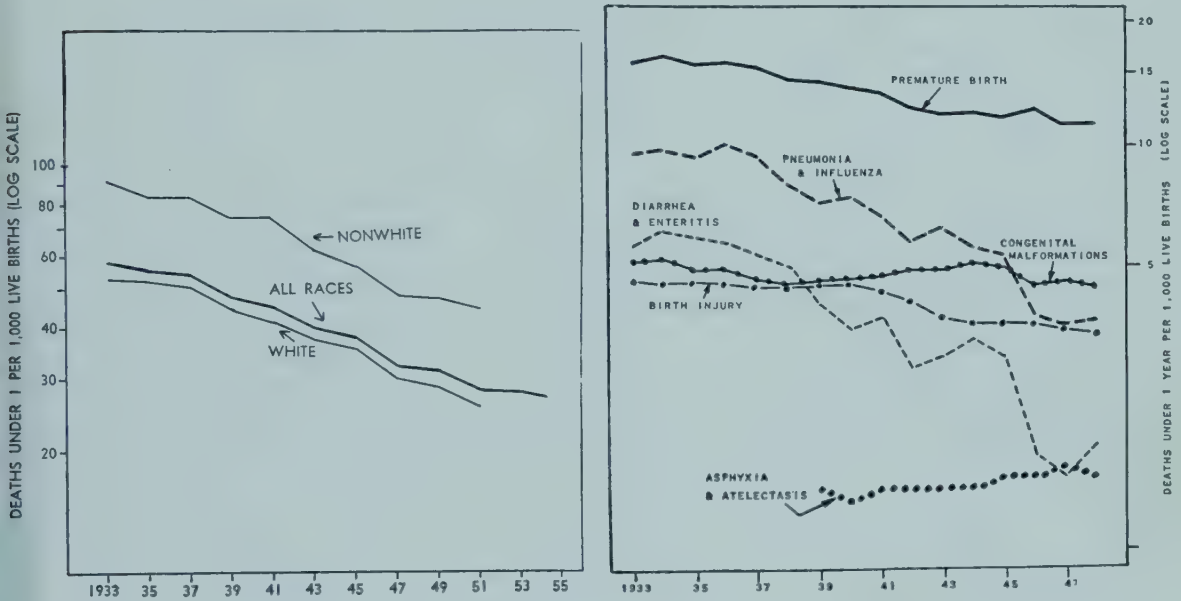


Fig. 16-2. Infant mortality by race and main causes, United States.

Left, infant mortality has decreased 50 per cent since 1933, but the rate for nonwhite infants is still about 60 per cent higher than for white infants.

Right, premature birth is still far in the lead as the main cause of death.

such as Connecticut and Iowa had a rate of about 21 deaths per 1,000 live births per year in 1952, and such states clearly need other indices of progress. On the other hand, Texas, in 1952, had an infant mortality of 34; Arizona, 44; and New Mexico, 47; and for such states the present mortality curves will continue to offer a valuable index of progress for a considerable time to come.

Inspection of the right-hand side of Figure 16-2 shows that most of the decrease in infant mortality has been due to better control of infectious disease; the progress which can still be made in this area is clearly limited. Congenital malformations and birth injury have shown relatively little decrease; both of these are dependent upon new knowledge and better prenatal and paranatal care to effect further reductions. Prematurity is still far in the lead as a cause of infant mortality. It is clear that this is the area which probably offers greater opportunity than any other for continued reduction in infant mortality.

Figure 16-3 shows the main causes of preschool child mortality. It should be noted that the scale has changed from that used for infants and is given in deaths per 100,000 population, age 1-4. Here again the deaths due to infectious diseases have shown a rapid decrease while deaths due to accidents have decreased relatively



slowly and are now in first place. Motor vehicle accidents have caused about 25 per cent of these accidental deaths.

These charts show some aspects of the problem. Of increasing importance is the mass of less exact information which is concerned with physical, emotional and mental health and with the prevention of illness. For example, more than half of all infants and young children have problems related to feeding, toilet training, or sleep-

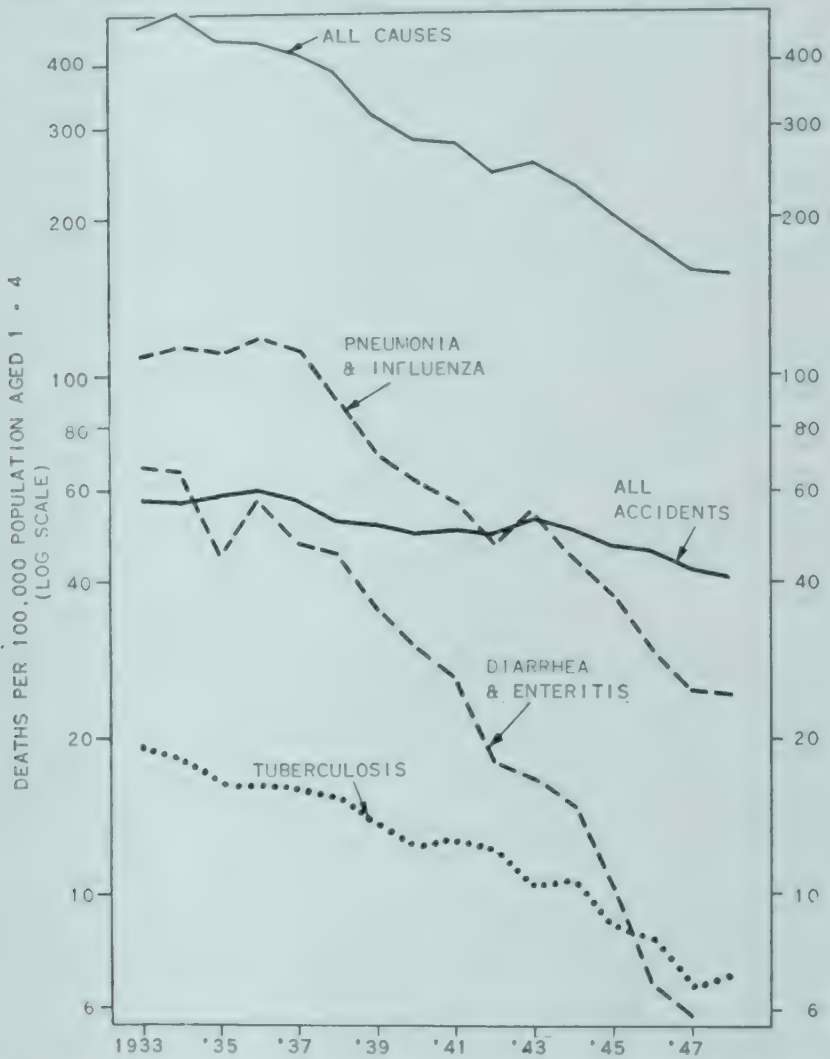


Fig. 16-3. Preschool child mortality (ages 1-4) by main causes, U. S. A., 1933-1948.

Deaths due to accidents have decreased relatively slowly and are now in first place. Motor vehicle accidents cause over one fourth of all accidental deaths in this age group.

ing, and their parents need advice on these matters. Or, again, planning is influenced by recent work which shows that about 5 per cent of all school children have impaired hearing which requires medical advice. The high incidence of uncorrected defects of eye and teeth is another example of the many problems in this area.

**Relation of the Child's Health to that of the Mother During Pregnancy.** There is increasing evidence that the prenatal health and care of the mother have a direct effect on the health and survival of the infant. On the other hand, recent studies of the influence of nutrition in the mother on the fetus and newborn infant present conflicting results which have important implications for public health policy.

Ebbs (1941) and his co-workers in Toronto studied three groups of pregnant women (see Table 16-1). One group of 120 women had low incomes and poor diets. The other two groups both had good diets, part of them being women with low incomes whose food intake was supplemented with proteins and vitamins and

Table 16-1. Maternal diet and condition of infant at birth

Diet	No. of Women	Miscarriages Per Cent	Stillbirths Per Cent	Prematures Per Cent
Poor	120	6.0	3.4	8.0
Good	260	0.8	0.4	2.7

Arranged from Ebbs and others, J. Nutrition, 22:515, 1941.

the rest were women with fairly adequate incomes who were advised regarding desirable foods. These latter two groups have been combined in Table 16-1 as having good diets. At the conclusion of this study it was found that 6 per cent of those on a poor diet had miscarriages, as contrasted with 0.8 per cent of those on a good diet. The corresponding figures for stillbirths were 3.4 and 0.4 per cent, and for premature births 8.0 and 2.7 per cent. These findings have been confirmed by Balfour (1944); Burke and others (1943). Stuart (1945) and his group in Boston found that there was a direct relationship between the weight of the newborn infant and the quality of mother's diet during pregnancy; thus over 90 per cent of the mothers who had a good or excellent diet produced children weighing over seven pounds, while only 23 per cent of the mothers who had a poor to very poor diet produced babies above this weight.

World War II offered opportunities to study the effect on the fetus of maternal diets which were so poor that they bordered on starvation. Smith (1947) studied the effects of the severe temporary starvation which occurred in Rotterdam and The Hague from late 1944 until June, 1945. The reason for the hunger in these cities was the general transportation strike against the Germans which began September 17, 1944, at the request of the exiled Dutch Government in London at a time when it seemed that Holland would soon be liberated. This did not happen, but the strike held for the entire period until liberation in May, 1945. Little or no food or fuel was transported to the major cities. The Germans guarded roads against smuggling with the hope that hunger would break the strike. The birth weight of infants which were born during the hunger period decreased by an average of over 200 gm. as compared with prewar birth weights. Antonov (1947) made a similar study in Leningrad during the siege of 1942 and found an average decrease in birth weight of 500 to 600 gm. The drop in birth weight was believed to be indicative of general lowered nutritional status in the infant and supported the thesis that the fetus is affected by the nutrition of the mother.

Taylor and his associates (1949) found that premature infants who are born of mothers having severe uncontrolled medical disease or serious obstetrical complications have a mortality rate which is four or five times that of premature infants born to healthy mothers who had no complications during delivery (see Table 16-2). They expressed the view that one of the best ways to reduce premature mortality is by preventing obstetric complications. The importance of a good diet



Table 16-2. Premature mortality by complication of pregnancy—stillborn and neonatal deaths

Classification of Pregnancy	Total Infants Born	Infants Lost	Per Cent Infants Lost
Uncomplicated	344	27	8
Complicated	133	49	37
Total	477	76	16

Arranged from Taylor and others, J.A.M.A., 141:13, 1949

during pregnancy in reducing the incidence of toxemia is discussed and emphasis is placed on the value of bed rest and other conservative measures for carrying nearer to term women with slight bleeding from placenta praevia or premature separation of membranes. These authors concluded that the major responsibility for reducing the mortality rates of premature infants rests with those doing prenatal and obstetrical work.

On the other hand, there are four careful studies which fail to support the above observations. Williams and Fralin (1942) were not able to establish a relationship between the dietary ratings of over 500 women in Philadelphia and the incidence of toxemia, prematurity, stillbirth, or birth weight of their infants. Sontag and Wines (1947) in a study of over 200 mothers and infants in Ohio were unable to find any significant correlation between the mothers' diet and the weight, length, or ossification level of the infant. However, it should be commented that these latter patients are described as from the upper middle class and it is possible that they did not fall below the critical level where a poor diet might affect the fetus.

Speert (1951) in New York and McGanity (1954) in excellent studies in Nashville were likewise unable to show any relationship between nutrition in the mother and the complications or outcome of pregnancy. Both studies were of low and low-middle socio-economic groups.

What is the implication of these conflicting data? A reasonable working assumption is that there is a point or zone below which dietary shortcomings do affect the fetus; that the limits of this zone are not known nor how many people in our national community eat diets which are so poor as to fall below this critical level. Although evidence is accumulating that the number of people on seriously deficient diets is not great, nevertheless the health officer who frequently deals with the lower economic groups has no simple means to pick out the mothers who need special attention. Furthermore, the objective is to promote good nutrition, not merely to avoid malnutrition. It, therefore, seems clear that continued emphasis on more prenatal care and on a better diet for pregnant women will result in more healthy babies. More hospital beds at the disposal of obstetricians for the use of mothers who develop complications during pregnancy is probably one of the best investments of money intended to reduce premature mortality. The human uterus is a far better incubator than any mechanical one.

**Distribution of Health Services for Children.** The Academy of Pediatrics Study. The most valuable publication on child health services of this decade is the report of the nation-wide survey conducted in 1946 and early 1947 by the American Academy of Pediatrics in cooperation with the Children's Bureau and the Public

Health Service (Am. Acad. Ped. 1949a). This survey gathered data from all physicians who care for children, from hospitals which serve children and from public and voluntary agencies both state and local which provide health services to children. The national report is supplemented by individual reports from more than half of the 48 states. Table 16-3 shows that 98.5 per cent of children under medical

Table 16-3. Children under medical care per day per 1,000 in the United States

Source of Care	Number per 1,000 Children	Per Cent
Physicians (home and office visits)	10.7	77.5
Hospital, including outpatient dept.	2.9	21.0
Community health clinic *	0.2	1.5
Total	13.8	100.0

\* Comprises visits to child health conferences, mental hygiene clinics and clinics for the physically handicapped. Adapted from Am. Acad. Ped., 1949, Supplement Table 13.

care on any given day receive this care from physicians in private practice or from hospitals and that 1.5 per cent of these children are seen in child health conferences, mental hygiene clinics or clinics for the physically handicapped. About 75 per cent of all private care for children, both when ill and when well, is given by general practitioners, 11 per cent is given by pediatricians and the remainder by other specialists.

A different distribution is found when the ill child is excluded and the data on well-child care are considered. Health supervision was defined as a visit for "health examination, immunization, regulation of feeding, etc." It is recognized that there was some confusion in individual cases as to whether a child should be classified as sick or well but it is believed that the data are valid. General practitioners reported that about one third of their visits to children were to well children and pediatricians said that more than half of their visits were for health supervision. Table 16-4 shows

Table 16-4. Health supervision for children (0-4 years) by source on an average day in the United States

Source	Number	Per 1,000 Children	Per Cent
Visits to children by private practitioners (home and office)	70,427	5.03	91
General practitioners	(48,729)	(3.48)	(63)
Pediatricians	(20,642)	(1.47)	(27)
Other specialists	( 1,056)	(0.08)	( 1)
Visits by children to child health conferences	6,964	0.49	9
Total	77,391	5.52	100

Adapted from Am. Acad. Ped., 1949, Supplement Table 158.

that physicians in private practice provide 91 per cent of all health supervision for infants and preschool children and that child health conferences give the remainder. The amount of health supervision given by pediatricians is surprisingly large in view of their relatively small numbers; they provide only 11 per cent of all medical care for children but 27 per cent of all health supervision.



Table 16-4 should not lead one to infer that all children were given health supervision by private physician or child health conference. The figures in this table refer only to children who did receive well-child care on an average day. How many children receive no health supervision is unknown. Although the number of visits made to private practitioners for health supervision on an average day is given, the number of children getting this service during the year is not shown. Only in the child health conferences is there a count of both visits on an average day and of the number of children seen during the year. The number of children under five who visited child health conferences was 872,418, or 6 per cent of the nation's 10,900,382 children in this age group in 1945 (American Academy of Pediatrics, 1949b, Supplement, Tables 1 and 118).

Health supervision, according to this study, comprises about one quarter of all medical care for children. There is no information regarding the amount of such preventive work 25 years ago to allow comparison; nevertheless, it is clear that the content of medical practice for children is changing in the direction of more health supervision for the well child.

It would be helpful to know the forces which have fostered this trend. Unfortunately, there are no exact data but it is thought that the most important factor has been the increase of knowledge about the physical, mental, and emotional development of children and about the prevention of illness; that the application of this knowledge has been greatly stimulated by the work of child health conferences and by the development of pediatrics as a specialty; and finally that the public has recognized the value of and wants this type of medical care.

It is worth while to point out that the situation outlined above is quite different from that in Great Britain and some of the northern European countries where the source of well-child supervision is largely from public clinics. In London, about 90 per cent of all well-child care for all economic classes is provided by public clinics. The private physician in those countries has been chiefly concerned with the ill child and the separation of responsibility for the well and the ill child has been much more marked than in this country. In Great Britain, for example, most health supervision is done by nurses and others who are trained as health visitors.

**Geographical Distribution of Health Services.** Health services are not evenly distributed throughout the country. This contrast is brought out clearly in the Academy study by giving the value of 1.00 to the rate of visits in the greater metropolitan counties \* and calculating the relative rates for each of the other county groups (see Table 16-5). Children in the isolated rural counties receive less than one-quarter as many visits for well-child care as do children in the greater metropolitan areas. It might be expected that child health conferences would be more numerous in the rural counties but the contrary is true.

**Public Organization for the Care of the Well Child.** Public programs for the care of the well child are a development of the past 50 years. As already noted they

\* The Academy study classified a greater metropolitan county as one which contains any part of the metropolitan area of the population centers of 1,000,000 or more people, namely, Baltimore, Boston, Chicago, Cleveland, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, St. Louis, San Francisco, Washington. A lesser metropolitan county contains at least one city of 50,000 or more people. A county that touches a metropolitan county is classified as adjacent. An isolated semi-rural county has at least one incorporated place of 2,500 or more inhabitants and an isolated rural county has no incorporated community of that size.

Table 16-5. Health supervision by source and by county group per 1,000 children under 5 years, United States

County Group	Rate of Visits Taking Greater Metropolitan Rate as 1.00			Total
	General Practitioners	Pediatricians	Child Health Conferences	
Greater metropolitan	1.00	1.00	1.00	1.00
Lesser metropolitan	0.58	0.96	0.53	0.69
Adjacent	0.70	0.13	0.16	0.45
Isolated semi-rural	0.59	0.16	0.12	0.40
Isolated rural	0.38	0.00	0.10	0.23

From Am. Acad. Ped., 1949, p. 128.

grew out of efforts which were begun by voluntary and private groups. In general, these programs have been designed to stimulate and supplement the services of private medical practice and to provide health supervision for a segment of the population which would not otherwise get such care.

Different patterns have developed for each age group. The health of the infant in the neonatal period is largely concerned with care in hospital and has become the responsibility of the health agency through its hospital inspection and maternal and child health divisions. The health supervision of the older infant and preschool child is largely centralized in child health conferences, most of which are operated by health agencies, a few by voluntary groups. Public programs for supervision of the health of children of school age are not as well organized as are services for the other two age groups, and the operation of such programs as exist is sometimes the responsibility of the health department, sometimes of the education agency, sometimes jointly, and all too often is the source of jurisdictional conflict. Public services for each age group will be discussed in order.

**THE NEONATAL PERIOD (BIRTH TO 28 DAYS).** Three major problems which arise in this age period have public health aspects: these are the prevention and treatment of prematurity; the prevention of epidemic diarrhea of the newborn; and the licensing of hospitals with regard to their facilities for both prematures and newborns. Included in this latter category is the approval of plans for the construction of hospitals which are to receive money under Public Law 725, 79th Congress, The Hospital Survey and Construction Act.

A few figures serve to point up these problems. The neonatal mortality is approximately two thirds and the deaths during the first day of life are nearly one third of the total infant mortality. The main causes are the same as those shown in Figure 16-3 for all infants, with the differences that prematurity, birth injury and congenital malformation are each of greater relative importance. Table 16-6 presents the same problem in another way by showing that efforts must be concentrated on the causes of death in the first month and especially on the first day. Many of these matters are the responsibility of the obstetrician and those who care for the mother during pregnancy and delivery, as has been discussed in previous sections. Here, we are concerned with the responsibility of the child's physician and of the health officer.



Table 16-6. Thirty-five year decrease in infant mortality by age groups

Age at Death	Infant Mortality Rate		Decrease
	1915 <sup>1</sup>	1950 <sup>2</sup>	Per Cent
6-11 months	22.0	2.7	88
1-5 months	33.6	6.0	82
Under 1 month	44.4	20.5	54
Under 1 day	15.0	10.2	32

<sup>1</sup> Mortality Statistics, 1915, p. 645; Birth Statistics for the Registration Area of the United States, 1951, p. 21.

<sup>2</sup> Vital Statistics, Special Reports, Vol. 37, No. 18, 1954.

*Prematurity.* Premature birth is a public health problem of the first rank (Lesser, 1950). That there exists widespread current realization of this fact is largely due to the persistent efforts of Dunham (1955) who has repeatedly pointed out for many years that "premature birth takes a higher toll of infant life than any other condition, and is one of the leading causes of death among the general population of the United States." It accounts for half of all neonatal deaths and one third of all deaths during the first year of life.

Dunham has succinctly summarized the premature problem: "To save these infants we must make increased efforts to prevent premature birth; get more detailed information on deaths now assigned to premature birth alone; spread knowledge of and facilities for the special care known to be needed by premature infants; and broaden through research the scope of knowledge in regard to problems of prematurity."

To accomplish these objectives requires a high degree of "systematized social action" (Mustard, 1944), and the core of most of the varied state premature infant "programs" may be found in the leadership provided by state health departments for the promotion of organized cooperation between physicians, nurses, hospitals and health departments to achieve: (1) the prevention of prematurity by better obstetric care, and (2) the provision of better medical and nursing care and after care for the prematurely born infant.

Some of the methods which have been successfully used to achieve this organized cooperation between interested professional groups are the financial assistance by health departments to hospital premature nurseries, especially those engaged in training and research as well as service, and the cooperation of state medical societies. Another important device has been the cooperation of state health departments and hospital associations with the state Committee on Fetus and the Newborn of the American Academy of Pediatrics. In this latter connection, the "Standards and Recommendations for Hospital Care of Newborn Infants—Full-Term and Premature" of the American Academy of Pediatrics has been a significant contribution to the problem of improving hospital care of premature infants.

The interest of state health departments in establishing public health programs for the care of premature infants is not especially new. In 1937, the Massachusetts Department of Public Health inaugurated a program (McKay, 1949) featuring arrangements with 48 hospital centers outside of Boston which were adequately equipped to care for premature infants, a transportation service, and assistance to the family for payment of hospital expenses.

In recent years, the Children's Bureau has stimulated the development of state projects for the care of prematurely born infants. In 1949, programs of this type were being financed in whole or in part by federal maternal and child health funds in at least 14 states. Details of these programs vary from state to state, and it is obvious that a great deal more testing in actual operation and research must be done before the true effectiveness of this new public health effort is demonstrated. A recent study (Children's Bureau, 1950) of one state program (Colorado) provides valuable initial evidence of this sort. Currently, the Children's Bureau in cooperation with a pilot state is aiding a large scale study of the effect of different kinds of hospital care on the survival of prematurely born infants. An example of an urban public health program is described by Wallace and others (1950).

Lesser (1950) has summarized important features of the various state programs as follows: "training of nurses and physicians in the care of premature infants; development of hospital standards and licensing, with emphasis on facilities and personnel for proper care of premature infants; consultation to hospitals (principally by nursing consultants) to raise the standards of care for full-term as well as premature infants; loan of incubators, together with consultation regarding their use; provision of transportation of premature infants to premature-infant centers; development of designated premature-infant centers and purchase of hospital care from them." He also lists measures designed to prevent prematurity such as: "extension of prenatal services, with emphasis on diagnostic services and the importance of adequate nutrition; obstetric consultation for complications during pregnancy; hospitalization for complicated pregnancy; obstetric consultation to improve management of the mother's labor and delivery in cases of premature birth (since most of the premature infant deaths occur on the first day of life); and publicity and general education activities."

There are many unknowns concerning prematurity. Eastman (1947) points out that there is no specific explanation for 60 per cent of all premature births. More research is needed on the best definition of prematurity, the causes of premature labor, the effect of social and economic conditions, the methods of care, the cause of special handicaps, the effects of different types of care on survival, and the long-range facts of growth and development of these infants. The value of research is illustrated by the recent demonstration that retrolental fibroplasia is due to too vigorous oxygen therapy and that this great source of blindness can be largely eliminated by reduction of oxygen (Rothmund (1954), Kinsey, V. E. (1954) and Lanman (1955)).

*Epidemic Diarrhea, Hospital Licensing and Approval of New Construction.* Epidemic diarrhea of the newborn has become a public health problem during the last two decades. This is partly a result of the various pressures which have pushed hospital deliveries from less than 40 per cent in 1935 to about 90 per cent of all births. The resultant overcrowding and understaffing of nurseries is a matter of public record. There is no doubt that hospitalization is good for the mothers; it is not so clear that it is as desirable for the baby.

For example, although diarrhea of the newborn was not reportable in New York State until 1946, a total of 28 nursery epidemics came to the attention of the State Department of Health during the six-year period, 1942 through 1947 (Trussell,



1949). There were 618 ill infants with 62 deaths. The problem is greater than these figures indicate since these data are known to be incomplete. Similar situations are reported from other states all over the country. Clifford (1947) has reviewed the literature and discussed the etiology, the importance and the control of this disease.

The prevention of epidemic diarrhea and other infections in newborn babies was the chief motivating force which influenced the thinking of the Committee on Fetus and Newborn of the American Academy of Pediatrics in 1954 as they drew up "The Standards and Recommendations for Hospital Care of Newborn Infants." A similar purpose was behind the earlier publication on this subject by the Children's Bureau, Bulletin No. 292, in 1943. These publications recommend that the medical staff of the nursery should be a part of the pediatric staff, be integrated with the obstetrical staff and so organized that the responsibility for all newborn and premature infants is fixed on one physician. There should be one physician, preferably a resident physician, assigned to the nursery who will be on call 24 hours a day and who will visit the nursery daily. Standards of care should be available in writing for physicians and nurses. The nursery should be located in the obstetrical division of the hospital; if there is no obstetrical service the nursery should be in an area away from all units where transmissible disease may break out.

The United States Public Health Service Regulations, Title 42, Public Health Chapter 1, PHS, FSA, require that any construction to qualify for federal aid shall provide not less than 24 square feet per bassinet in full-term nurseries; 30 square feet are recommended. There shall be no more than 12 bassinets in each full-term nursery; eight bassinets are recommended. "Suspect" nurseries must provide 40 square feet per bassinet and not more than six bassinets per nursery. The total number of bassinets in "suspect" nurseries should be about 10 per cent of the total number of bassinets for full-term infants. These regulations were intended for new construction, but are rapidly being applied as minimum standards for current facilities. Thus, the New York State Sanitary Code, Chapter 2, Regulations 35, which went into effect on January 1, 1949, set up standards for all nurseries in upper New York State, of which the chief requirements are as follows:

Facilities for isolating "suspect" or ill infants.

Individual equipment for each infant except for weighing scales.

Common bathing and dressing tables prohibited.

Terminal sterilization of formula, which is to be in individual feeding bottle with nipple and cap attached.

Separate nurses for sick and well infants.

No common carriers for bassinets.

Nurse-baby ratio of 1 to 12, around the clock.

Twenty-four square feet of floor space for infant, or separate cubicle.

Not more than 12 infants per nursery.

No intercommunicating nurseries.

Running hot and cold water for handwashing in each nursery with control by elbow, knee, or foot valves.

It was recognized that overcrowding of nurseries was the result of an unexpected demand for hospital delivery and that hospitals were making every effort to improve their facilities; therefore, the regulations provided for deferment of enforcement of the last five items upon request of the hospital until not later than January 1, 1951. Other states and cities are framing similar regulations. Detailed suggestions regarding

the design and equipment of newborn and premature nurseries, "suspect" nurseries and formula rooms may be obtained from the Division of Hospital Facilities, Public Health Service or from the Division of Research, Children's Bureau, of the Federal Security Agency.

*Rooming-In.* The above standards and recommendations are aimed chiefly at reducing cross infection and, therefore, making the nursery safer for the baby. Recently, there has been considerable interest in other aspects of newborn care. The nursery in any large hospital is not unlike a factory assembly line. Work has to move on schedule and there is little time for individual attention. Both architects and hospital administrators have been prone to cut the nursery facilities and staff to the minimum acceptable standards. It is necessary to see and hear the bedlam in a large nursery during the half hour before feeding time and to note the work load of the nursing staff to understand what is meant.

The "rooming-in" plan is an arrangement designed to correct some of the shortcomings of the hospital nursery by having the newborn infant in the room with his mother for most of the time after the first 24 to 48 hours of life. The objectives are to allow the mother to become acquainted with, enjoy, and express her affection for her newborn baby; to foster breast feeding and enable the baby to have individual attention from his mother from shortly after birth; and to teach the mother the correct care of her new baby while she is still in the hospital. Rooming-in programs have been described by Jackson (1948). These plans are still experimental and more research is needed. Early ambulation and the great reduction in average length of hospital stay are recent and pertinent factors.

**CHILD HEALTH CONFERENCES.** The child health conference is the best device yet developed for providing health supervision to a large number of children who need this care and who do not otherwise get it. This is accomplished through services provided by the conference staff, and through referral to, or cooperative effort with other physicians or agencies. Child health conferences are also one of the chief areas for training doctors and nurses in the care and study of well children.

Child health conferences work under the handicap of interrupted care. They assume responsibility for the child only when it is well and refer it to a private practitioner or hospital when it is ill. As yet, no satisfactory plan has been widely developed for transferring information between the individuals assuming these two responsibilities. The solution of this problem must be accomplished if children are to be as well served as they should be.

It has been noted already that children who receive health supervision obtain most of this service from physicians in private practice and the remainder from child health conferences. There is no information as to the number of children who received no well-child supervision but everyone who has worked in private practice or in organized programs knows that there is a considerable number who receive very little if any health supervision.

It has been noted also that children in rural areas get less health supervision both from physicians in private practice and from child health conferences than do children in urban areas. During the year of the Academy study two-thirds of the counties in the country had no child health conferences, and nearly one third of all the children under five years of age lived in these counties. Table 16-7 shows that the greater metropolitan counties had approximately four times as many conference



Table 16-7. Well-child conferences. Availability of services in urban versus rural areas, United States, 1946-1947

	Number per 1,000 Children Under 5 Years		
	Greater Metropolitan Counties	Isolated Rural Counties	Entire United States
Sessions	23	6	11
Patients	118	27	62
Visits	422	44	182

Adapted from Am. Acad. Ped., 1949, Supplement Table 117.

sessions, four times as many patients and ten times as many visits to child health conferences per 1,000 children as did isolated rural counties. It is pertinent to note that one of the purposes of Title V of the Social Security Act, which provides grants-in-aid to support these services, is stated to be the extension and improvement of services "especially in rural areas and in areas suffering from severe economic distress." It is clear that this purpose is not yet fully accomplished.

The early milk distribution stations and the child health conferences which developed from them were largely supported by voluntary effort. This responsibility has gradually been taken over by departments of public health until at present about 80 per cent of the child health conferences are operated by official agencies, and the remainder by voluntary ones.

The Academy study showed that practically all conferences gave advice on feeding and training and provided public health nursing follow-up services in the home. Eighty per cent of conferences routinely gave immunizations for diphtheria and smallpox and over 60 per cent gave immunizations against whooping cough.

The medical staffing of child health conferences is done by health officers, pediatricians and general practitioners. General practitioners conduct about one half of the clinics in all county groups, both rural and urban. Health officers conduct nearly half of the clinics in rural counties but hold very few conferences in urban counties. The reverse is true of pediatricians, who are responsible for nearly half of the urban clinics and very few rural ones.

Infants and preschool children comprise the age group usually served by the child health conference. The Academy study, however, shows that most of the service is provided for infants and that only about one quarter of these infants are carried through the preschool years. The reasons for this are not clear. However, it is suggested that one of the best ways to evaluate the mother's satisfaction with a clinic service is to determine the relative number of infants who continue to make use of this clinic during their preschool years. Most mothers understand the value of bringing their children to a clinic so long as feeding is a problem and until immunizations are completed. The worth of subsequent visits is less tangible and depends to a large extent upon the interest that the physician takes in the emotional problems of the growing child as discussed below under anticipatory guidance. It is probable that most of the children who discontinue their attendance at child health conference after the first year receive no further health supervision until they reach school.

*Eligibility.* Some conferences admit only children residing in the county or cit

in which the conference is held. About one quarter of the conferences had restrictions based on economic status; such restrictions were found chiefly in metropolitan counties, rarely in isolated counties. Very few (4 per cent) required referral by a physician (Am. Acad. Ped. 1949a).

Eligibility rules are set up to restrict the use of limited public facilities to those who need them and also to protect from tax-supported competition the private practitioner upon whom the nation depends for its medical care. The question occasionally arises as to whether these services are being used by a significant number of people who could well afford to pay for such care. We have noted that 6 per cent of the nation's children under five years visited child health conferences in 1946. Data on family income in this country at the time of the study showed that 10.7 per cent of the families had an income of less than \$1,000 a year and that 18.5 per cent of the families had an income of less than \$1,500 per year (U. S. Department of Commerce, 1949). These figures suggest that there are families who cannot afford to pay for well-child care and whose children do not now receive such care through child health conferences.

*Frequency of Visits for an Individual Child.* Schedules and suggestions for frequency of visits are given in most of the state and local manuals on the child health conference. As many as four different types of visits are described in these manuals, as follows: complete conference with physical examination; conference including interview with physician where the physician inspects the child but does no physical examination; conference with the nurse alone who inspects the child and interviews the parent; and home visit by a public health nurse.

The American Academy of Pediatrics and the Children's Bureau recommend that the well child be seen every month during the first half year, about three times during the second six months, every three months during the second year, and every six months from two to six years of age. Most health department manuals recommend that complete physical examinations be done routinely at somewhat less frequent intervals, and many of them recommend the interspersal of other types of conference.

The current practice in the conferences operated by the Johns Hopkins University School of Hygiene and Public Health, which developed from experience in private practice, is for the nurse to make a home visit within 48 hours after the mother leaves the hospital; other home visits are made if necessary; and then for the mother and child to attend the clinic at monthly intervals for the first six months or until the initial series of immunizations is complete. Subsequent visits are at one- or two-month intervals for the remainder of the first year, depending on the needs of the particular child. Visits during the second year are at three- to four-month intervals and at 6- to 12-month intervals thereafter until the child goes to school. The type of visit, especially as regards the content of the physical examination, is variable and is further discussed under the section entitled "Content of Well-Child Care."

The early home visits are extremely valuable. The new mother is on her own for the first time and usually appreciates an opportunity to ask questions and settle apprehensions. It is also made possible for her to telephone the nurse or the doctor during these early days at home. This is a modification of the "telephone hour" which many practicing pediatricians find valuable. Mothers with their first baby need



to come more frequently than multiparas and of course mothers and children with problems need extra visits. Problems tend to be concentrated at certain age periods, thus, many questions arise during the first few months, which is the period of rapid increase in caloric needs, of frequent additions to the diet and a reduction in number of feedings, particularly night feedings. This is often followed by a brief period of smooth sailing which leads to a new series of problems as the baby begins to stand, and to walk and "get into things" from 9 to 12 months of age. At this time the mother often has questions about discipline and sleep, about new feeding problems and about toilet training. The appointment schedule is made flexible to allow for such eventualities.

*Frequency of Conference.* The frequency of conference will depend upon availability of staff and patient load. Ordinarily, conferences should not be held less than once a month, this being the maximum span of time ordinarily desirable between visits for regulation of feeding during infancy and for the giving of immunizations. Two months is usually too long and a six-week interval does not easily allow for an established conference day, such as every fourth Thursday of the month; such a fixed date makes it easier for the parent to remember and plan attendance.

*Appointment System and Patient Load per Physician Hour.* A recent survey of child health conferences by Harper and Wishik (1951) obtained data about the patient load per physician hour, which is pertinent to a discussion of an appointment system.

Table 16-8 shows that over one third of the health departments reported that their clinics averaged more than 10 patients per physician hour. The average for

Table 16-8. Patient load per physician hour in child health conferences. Averages from 200 health departments in 33 states

Health Departments	Average Number of Patients per Physician Hour				
	Under 5	5-9	10-14	15 +	Total
Number .....	35.0	96.0	45.0	24.0	200.0
Per cent .....	17.5	48.0	22.5	12.0	100.0

From Harper, P., and Wishik, S., *Am. J. Pub. Health*, 41:312, 1951

the entire country was 8.4 patients per physician hour or about seven minutes per patient. The patient load is actually greater than is indicated in Table 16-8 because of the method of tabulation. For example, one health department reported "28 patients per clinic session of one to two hours." This was tabulated as 14 patients per physician hour.

Such a heavy patient load encourages the system wherein all patients are told to come at 1 o'clock, where they are registered and "talked in" by the nurse between 1 and 2 o'clock, see the doctor between 2 and 3:30 and are "talked out" by the nurse as opportunity offers. Usually, such a program results in a noisy, crowded clinic, deters some mothers from coming who have other children whom they cannot leave for such long periods, and is wasteful of the patient's time.

The use of an appointment system which gives both the date and hour of visit will greatly improve the service of most child health conferences. It conserves time

for both the staff and the client. Such appointment programs are being gradually introduced and a discussion of some of the problems involved may be useful.

Hansen (1950) has studied broken appointments in a child health conference where the people had never before been accustomed to an appointment system. She found that about one third of the appointments were broken over the study period in the first year of the new system. Illness in the child or family was the cause in nearly one half of these instances: the family had merely transferred responsibility from the "well-baby doctor" to the "sick-baby doctor" and failed to notify the former. Obviously, this source of broken appointments does not occur when the same physician sees the child both when he is well and when he is ill. Inclement weather, change of address, change to another conference, or criticism of the conference's service were the other most important causes of broken appointments.

This study made clear the need to explain the purpose and value of the appointment system to each mother and to emphasize her responsibility if she is to participate in the benefits. It also suggested the desirability of continual alertness about the waiting time of individual patients and about reasonable criticisms which should not be neglected.

One method of avoiding waste of physician's time because of broken appointments is to schedule two patients for the first appointment and for occasional subsequent appointments. This means that if both patients arrive on time, one of them must wait, but this is clearly an improvement over the system of having all patients come at the same hour. On the other hand, periods should always be allowed for the patient who comes without an appointment and who urgently needs to be seen, or for the unexpected problem that takes more than the allotted time. Clinics where group teaching of mothers is done may find that careful planning is necessary to arrange a suitable appointment system.

The seven minutes average time allocated to each patient by physicians in child health conferences across the country contrasts with the custom of most pediatricians in private practice to allow 15 to 20 minutes for return visits of well children and longer for new patients and for problems. Lightening of the patient load in child health conferences should be attempted, but it is clear that the amount of physician time per patient will not, for a long time, approach that available in pediatric practice. The problem for administrators of child health conferences, therefore, is to so utilize nursing and physician staff that the best use is made of available personnel. This will be discussed further under the section devoted to the activities of the public health nurse. However, it is pertinent at this point to state our view that a physician should average at least 10 minutes per child; the reasons for this will become clearer in the section devoted to anticipatory guidance. This amount of time should be made available if necessary by having the child see only the nurse on some visits and so reduce the number of patients per physician hour.

Arguments for this point of view include the fact that child health conferences have been influential in the past in setting standards of well-child care in many communities and should continue to keep their standards high; furthermore these conferences are the chief area for training in well-child care.

*Content of Well-Child Care.* It will be helpful to define what is meant by "well-child care." The services to patients which are provided in our own conferences may be listed under 10 headings, as follows: (1) complete history (including records of



height, weight, etc.); (2) physical examination; (3) regulation of feeding; (4) immunizations; (5) laboratory; (6) anticipatory guidance; (7) advice in handling of behavior problems; (8) periodic appraisal of child's physical, mental, and emotional status and growth; (9) nursing advice and follow-up; (10) consultation with or referral to private physicians, nutritionist, medical social worker, etc.

To this might be added a variety of methods for the education, particularly of mothers and of staff, in the management of the growing child. These items will be discussed briefly.

**History.** "Let the mother talk" is a rule that cannot be quoted too often. Her talk may be guided by an occasional comment or question, but she should be allowed and encouraged to express her problems in her own language; merely putting her difficulties into words will frequently show her the solution. Contrarily, one of the poorest ways to obtain a satisfactory history is to set out routinely to obtain the answers to a predetermined series of questions.

The patient may first be seen by the nurse, who takes a brief history and writes down the salient points. The physician, when he sees the patient should review this history and encourage the mother to present her own problems in her own way. One or two remarks are made to break the ice, followed with, "How is everything going?" or "What can I do for you?" or something similar. The physician tries to allow a mother whatever time is necessary to obtain an adequate understanding of any problems she may have. Only after this has been accomplished is the clinic form introduced, with the explanation that additional facts are needed for the record. It should be emphasized that history-taking is something that goes on all during the visit. It is necessary to be alert to the partially revealed problem which may become apparent during physical examination, during the giving of immunizations or at any other time.

**Regulation of Feeding.** The feeding of infants and children has been so simplified and standardized that this phase of a physician's work has decreased both in importance and in consumption of time. It is no exaggeration to say that over 95 per cent of young babies can be adequately fed on a formula of cow's milk (either evaporated or whole) sugar and water, plus added vitamins. However, the physician has such a keen recollection of earlier days when feeding was a real problem that he frequently hesitates to delegate any responsibility for regulation of diet to the nurse. Yet it is probable that a better division of labor would result if the nurse assumed more of the work of routine addition of solid foods and the physician devoted more attention to anticipatory guidance and to discussion of the patient's current problems as pointed out below.

**Physical Examination.** Two kinds of physical examination are done in our child health conferences: complete examinations at certain age levels; and partial examinations at each visit. Complete examinations are made on the initial visit, at 6 months, at 12 months, at 24 months and at 36 months and whenever the physician feels that an additional complete physical examination is necessary. Limited examinations are done on every visit at which the child sees the physician. The child is stripped for rapid inspection of color, nutrition, skin turgor, and for any gross abnormality. Attention is then given to things which have been found important to observe as the months roll along. A different thing is emphasized each month. For example, the sternocleidomastoid muscle of all newborns is felt to find the occ.

sional infant who develops a hematoma with resultant shortening and wry neck. About the third month of age the heart is re-examined to detect any murmurs or other abnormalities which were not present at the initial examination. About the fifth month observation of the legs is begun, during that period when it is sometimes difficult to distinguish between the bowing which is physiological and that which is due to rickets. A little later, concern is about the retraction of foreskin in boys and patency of the hymen in girls. When the child first begins to walk, attention is focused on his legs, feet, and gait, with a thought for the rare case of congenital dislocation of the hip. These are examples of the way in which limited examinations are geared to the growth and development of the child.

Immunizations. Our current practice is to give three doses of a triple vaccine containing antigens against diphtheria, pertussis and tetanus at monthly intervals beginning at the second or third month. A booster injection is given about a year later and again in the fourth or fifth year. A smallpox vaccination is given during the first year.

The trend toward giving immunizations at an earlier age has received great impetus from recent work. The classical studies which demonstrated that the infant has a more efficient mechanism for developing antibodies after six months than before this age have been extended and amplified. It has now been shown that most infants can, during the first few months of life, develop antibody levels to the above three antigens which are sufficient for protection, although not so high as the same stimulus would produce at a later age and new information has been found which accounts for some of those infants who fail to develop protective levels. Bell (1948a,b) has shown that there is an adjuvant effect from the giving of diphtheria and pertussis antigens in combination which results in a higher level of immunity against diphtheria when infants are immunized before six months than when an infant after six months is immunized for diphtheria alone. (See Table 16-9.)

Table 16-9. Adjuvant effect of combined diphtheria-pertussis antigen. Combined antigen given before sixth month versus diphtheria alone given at 6 months or later

Antigen Given	Age at 2nd Dose	Number Tested	Schick Positive	
			Number	%
Diphtheria-pertussis	2-5 mo.	201	15	8
Diphtheria alone	6 mo. +	236	23	10

Arranged from Bell, J. A., J.A.M.A., 137:1009, 1948.

The strongest argument for the early institution of immunization procedures is the need for protection against pertussis. Pertussis has been and still is an extremely dangerous disease in the very young infant even though there is now evidence that hyperimmune sera and some of the antibiotics may offer effective treatment. At the present time nearly half of the mortality due to pertussis occurs in the first six months. It is clear that active immunization must be given early if it is to be effective. A discussion of the ability of the very young infant to develop protection is given in Chapter 1 under whooping cough.

It is also to be noted that the great reduction in clinical and subclinical diphtheria by means of active immunization has led to a new problem. A generation ago, before active immunization was so widespread, it was safe to assume that most



infants were protected against diphtheria during the first few months of life by antibodies acquired transplacentally from their mothers. Now the situation is changing and fewer mothers have a sufficiently high antibody level to afford significant protection to their infants during the early months of life.

The two chief arguments for the inclusion of tetanus in the triple antigen is the avoidance of the need for giving antitoxin containing horse serum at a later age, and secondly, the fact that about half of the children admitted to hospitals with clinical tetanus have not had antitoxin. These children either had not had any recognized portal of entry or their wound had been so minor that antitoxin had not been given. Active immunization against tetanus provides the only means of protecting such individuals.

Booster doses of the triple antigen should be given about one year after the end of the initial series and at three or four year intervals thereafter. This practice has developed as a result of studies which showed that active immunity in many children is quite transitory but that a single stimulating dose will not only restore but surpass the pre-existing high immunity levels. The number of booster doses which should be given is still a moot question and will probably always require some individualization.

At this point we digress briefly from this discussion of the work of the child health conference to note other methods of mass immunization for those children who are not immunized by their family physician. Immunization clinics, preschool roundups and school health programs are among the administrative measures which are used to get a large number of children injected. These procedures all have their place, especially in areas where child health conferences are infrequent or do not exist. (This will be discussed further in the sections on immunization and on health programs for children of school age.)

**Laboratory.** Hemoglobin determinations, urinalysis, serological tests for syphilis and tuberculin tests are the only laboratory procedures done with any frequency. None of these is routine, although we are coming to the view that regularly scheduled hemoglobin determinations would be valuable in our nonwhite population.

**Anticipatory Guidance.** Anticipatory guidance is the term used to describe attempts to discuss the child's behavior with parents in advance of the time when such behavior patterns may pose real problems. About a dozen of the most commonly occurring situations of early childhood have been selected and listed on record forms as suggested topics for discussion. For example, if there is opportunity to talk with the mother before delivery, and if she has an older child, she is told that rivalry and jealousy of the new baby are natural reactions in the older brother or sister and the methods of dealing with this problem are considered.

On the first visit with the new baby we discuss the need for flexibility in the amount and time of feeding and explain this on the variation in appetite which is common to all of us. We say that the breast-fed baby takes what he wants, and since no one knows the exact amount taken, no one is concerned. But the bottle-fed baby gets a prescription for a given number of ounces of formula to be divided equally into the prescribed number of bottles. We say that this does not mean that the baby should always take just that number of ounces, no more, no less. In this way we try to prepare the mother to allow her child some part in deciding how much he shall eat. At a later age we include one session where we mention thumb sucking, handlin

of the genitals, fear of strangers, etc., and say that these are reactions to be expected in most babies and are not a cause for anxiety.

It is necessary in this type of work to be continually alert to the danger of talking too much to the mother about possible problems which she may encounter at the risk of not allowing her sufficient time to discuss her own immediate problems. Brief mention of a few items serves to inform the mother that the physician is interested in her problems and also acts as an opening wedge for further discussion if the matter becomes of concern to her at a later time.

Full-blown behavior problems are becoming less important as a part of well-child supervision, particularly as staff members become adept in anticipatory guidance. For example, 20 years ago anorexia was an important subject in pediatric circles. One of the prominent pediatricians of that time said that anorexia and the treating of feeding problems had built his house for him. Most pediatricians now would feel that the development of a severe feeding problem in a baby who had been continuously under their supervision would reflect on their professional ability. However, behavior problems of this type are still frequent in areas where child health services are newly introduced. Our own experience and that of other clinics indicates that more than one half of all children, particularly first children, have problems concerned with feeding, elimination, or sleeping. These rarely become serious if there is proper guidance by the physician and intelligent handling by the parent.

It may be argued that the accomplishment of this type of well-child care will require too much time. On the contrary, it is the experience of most pediatricians that discussing these problems with the mother actually saves time. It is true that a longer appointment must be allowed when such discussions are initiated, but the cumulative effect of repeated small doses of anticipatory guidance is such that a little of this may be included even in a 10- to 15-minute visit.

This outline of the content of well-child care clearly suggests that to achieve success in this field there is need for continuity of contact between doctor and patient over a relatively long period of time. The mother does not usually bring her difficulties out into the open on her first visit, and such things as feeding problems and temper tantrums may require several months for solution. The physician should take time to listen to and to discuss the patient's problems but from a practical viewpoint it must be recognized that the patient load per physician hour in the majority of child health conferences is too large to allow this.

*The Public Health Nurse.* The public health nurse is primarily a health educator. This fact should not be forgotten in the press of her responsibilities for the smooth operation of the clinic program and she should not do work which could better be assigned to a clerk or to a volunteer worker. The new mother-new baby situation offers a particularly fine opportunity for the nurse to help and thus to do some teaching. In many agencies a large part of the nurse's time is devoted to this part of the population.

The nurse is also the one who gives some continuity to the child health conference work; she sees the patients at home between clinic visits and should be available by telephone. The question is how to make most effective use of her time and ability in combination with that of the physician.

There can be no standard solution to this problem; the patient load and the interests and abilities of both nurse and physician will require varying patterns.



However, some types of practice have been found to foster good teamwork. When the nurse takes the initial or interval history, the doctor should read it preliminary to his talk with the patient.

In large clinics, where more than one nurse is present and where clinic facilities permit, it may be most effective to have a nurse to work with the doctor. At least the nurse should be in the room when the doctor gives his final instructions. She should participate in this, bring to his attention facts which he may not know, and make certain that the patient understands what has been recommended. This pattern obviates need for the nurse to "post conference" the patient separately and avoids the confusion which sometimes results from two interpretations of the same orders. It is clearly undesirable to have an inflexible rule that the nurse shall have a conference with the mother following her visit with the doctor, as occasionally happens, even in situations where the physician takes time to listen to and discuss the mother's problems and to assure himself that she understands his directions. The need for a "post conference" between nurse and mother should be determined on an individual basis whenever possible. It has been noted already that listening to the mother is a most important part of history taking; it is also essential to all other phases of a well operated conference.

The question of whether or not the nurse should give the immunization is frequently warmly debated. It may be pointed out that nurses in hospitals are routinely expected to give hypodermic injections, which is certainly as responsible a procedure as is the giving of an immunization. Our practice is to have the nurse give the immunization when the child comes to the conference for that alone. However, it has been found preferable for the physician to give the immunization when this is only a small part of a complete visit.

The practice of interspersing occasional nurse conferences between the regular medical child health conferences is worthy of further trial. The physician is not present. A good indication of the value of such conferences will be obtained rather rapidly by observation of their popularity with mothers. At this point it is pertinent to note recent studies (Fisk, 1950) which put the cost of the nurse home visit at over \$3.00 each. This may be an added argument for the nurse conference.

*Personnel.* The basic staff for operating a child health conference is a physician, a public health nurse, and some clerical assistance. It is probably useless to try to operate a conference without a public health nurse, for in this situation services are available only on the clinic days when the physician is present. A nurse is required to provide any degree of continuity and to give advice and help between clinic visits. Additional staff which are available in larger clinics either to give direct service or, more frequently, to give consultation include a medical social worker, a nutritionist, a dentist and a child psychiatrist. The contribution of the dentist to these programs is described in Chapter 17.

Suggestions regarding organization, layout and equipment of a child health conference are given in the Children's Bureau publication No. 261, entitled "The Child Health Conference"; in Architectural Record's Building Types Study No. 6 and by Handley (1948).

*Evaluation of Clinic Services.* There are a great many people involved in providing health supervision. In many child health conferences these workers are largely independent of one another. Most health officers have no real information

about the quality or efficiency of services being rendered in the various conferences under their supervision, except as they occasionally visit those clinics and form personal estimates of the caliber of the individuals working there.

One of the greatest needs is for some method of continual evaluation of the work being done in the various conferences operated by a single administrative agency. Statistics which merely give the total number of child visits or the number of immunizations performed have very limited value. It is more important to know how many patients are seen per doctor hour, how many times the average child is seen during the first year, during the second year, and so forth; it is more valuable to know how many children fail to complete their immunizations by the sixth or seventh month than to know how many total immunizations have been given. The great need is to devise some simple, relatively easy method of providing day-to-day or month-to-month figures which will give the health administrator some index as to the quality of work and the efficiency of his various clinics.

*The Child Health Conference as a Training Area for Health Supervision.* The changing content of medical practice for children in the direction of more health supervision for the well child has been noted, together with the fact that approximately one quarter of all visits to children are for health supervision. This change in the content of practice has not been accompanied by a similar change in medical education and hospital training; these latter are still largely concerned with the ill child.

The child health conference is at present the single most important area for obtaining experience in health supervision, yet the Academy survey of pediatric education showed that more than one half of the interns and residents on approved pediatric services failed to obtain adequate training in this area. Rotating interns and general residents receive even less experience in health supervision. This is confirmed by a recent survey of 217 health departments in 33 states by Harper and Wishik (1951) which revealed that only 13 per cent of these agencies used any of their child health clinics for the training of interns or residents. This failure to utilize the training opportunities in these conferences contrasts with the view expressed by the great majority of health officers that training should take place in the child health conference. It is pertinent to comment on the factors which underlie this situation and to consider corrective measures.

It must be admitted that child health conferences as usually operated do not provide adequate training in health supervision. The great defects are lack of adequate facilities with which to work, the heavy patient load per physician hour, the lack of any teaching program in most clinics, even in these conferences which are used for training, and the lack of continuity in the relationship between the student physician and the mother and child clients. One result has been the notorious lack of enthusiasm on the part of house officers for work in such clinics even though they recognize that experience in health supervision is valuable.

These points may be illustrated by noting some of the measures required to provide adequate training in a child health conference. Space must be provided for each house officer to interview and examine. An appointment system must be set up so that the same house officer sees the same patient on successive visits. The patient load per student physician must be limited to the number that he can handle with thoroughness; our experience is that the physician in training needs 20 to 40



minutes per patient, including time to discuss problems with senior staff. All of this will require more paid staff of teaching caliber and will offer certain administrative problems. It is clear that this is a program to be undertaken and financed jointly by a health department and teaching hospital or medical school.

*Comment.* Child health conferences have contributed greatly to the problem of providing health supervision for children who need such services and also are one of our chief areas for training in the care of well children. But it is also clear that these conferences work under the handicap of discontinuous service; that they foster separation of responsibility for care when a child is well and when he is ill. Such separation of responsibility has been and still is necessary, but this does not alter the fact that the child will be best served when the same physician, or group of physicians, assumes responsibility for his care both when ill and when well, provided only that these physicians bring the same enthusiasm and ability to the field of health supervision that in the past they have devoted to the care of the ill child. The changing content of medical practice in the direction of more health supervision is accelerating. Such work already constitutes more than half of the practice of pediatricians and the interest of the general practitioner in this field is growing.

**CONSULTATION SERVICES.** Many states have a panel of pediatric consultants who agree to provide consultant services for children who need such assistance, usually at a flat fee fixed by the state health agency. More formal pediatric consultation clinics have grown up in other states; those in Maryland will be described. Such clinics are sponsored by the State Department of Health and are held in 13 of the 23 counties of the state, usually at monthly intervals. They are staffed by Board pediatricians who are in private practice and who do this work on a per diem basis, and by the two full-time pediatric consultants on the staff of the State Department of Health. Patients who offer diagnostic problems are referred from child health conferences or by their private physician. Such clinics are usually held in the local hospital or health department where x-ray and laboratory facilities are available, including electrocardiogram and basal metabolism in some instances. If diagnosis cannot be made with the evidence at hand, arrangement is made for referral to a local hospital or to one of the teaching centers if that seems advisable. When the diagnosis is established, a summary of the cases is sent to the referring physician, together with suggestions for continued therapy. It is emphasized that these clinics are for diagnostic rather than therapeutic purposes. They have proved to be a valuable adjunct to the Maternal and Child Health program.

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# 17

## HEALTH SERVICES FOR CHILDREN OF SCHOOL AGE

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"Health services for children of school age" is defined as *services for the promotion of physical, mental, and social well-being in children of school age*. This age group includes children between the ages of approximately 6 and 20 who are or might be in any of the usual 12 grades of the American school system, and does not include nursery school or kindergarten groups or those who have completed twelfth grade work, regardless of their chronological age. Health has been defined by the World Health Organization as "a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity" (Chisholm, 1948). Thus, health services for children of school age include those rendered through health supervision—personal and environmental, and through health education and guidance.

It is assumed that a person is the product of the interaction of his heredity (or genetic potentialities) with his environment and that, with few exceptions, at least some alterations in the environment are possible when necessary to permit the best development of whatever heredity has seen fit to give to an individual. It seems clear, therefore, that efforts toward a better world will be largely concerned with providing an environment for children which will further the "healthy development" of each individual. Provision of an optimum postnatal environment for each child will depend first and foremost on the parents, their health and knowledge of health, and their desire and willingness to help their children to maintain health from birth onward. In addition, the health and health facilities of the community are powerful environmental factors in the child's growth and development, and the school must be recognized as possibly the most powerful of these factors.

The health services (diagnostic, therapeutic and educational), as previously defined, which may be provided during the school years, will depend upon the home, the community, and the school. Though the preschool years are generally considered as the most important to the development of a healthy body and personality, the school years—those in which a child passes through puberty and adolescence to approach adulthood—are certainly a close second. For the sake of clarity, health services for children of school age, though interdependent throughout, will be discussed separately as they relate to and are supplied chiefly by: (1) the home, (2) the community, and (3) the school.

### HEALTH SERVICES IN THE HOME

The health services which a child receives whether in the home, the community, or in the school will depend largely upon the parents. The parents' approach to health may be anything from that of waiting until a person is all but dead before seeking medical care to that of desiring regular, periodic health supervision for the whole family. Self-medication may be the exception or the rule. The family may be one which can afford only free clinic care, one which receives all medical care from a general practitioner, or one which insists on specialists throughout—pediatrician for the children, obstetrician for the mother, internist for adult members, and specialist's care for those diseases recognized as specialties.

Physicians, nurses, social workers, teachers, and many others working in the interests of public health are all in a position to influence parents to seek better health for themselves and their children; but only as people become fully aware of the meaning of health will they desire it enough to seek it out at all costs. Thus, those wishing to promote better health for all children must work toward better health education for parents, must bring pressure to bear on some parents to make environmental and physical corrections possible for their children and themselves, and must make various services available to them at a minimum expense of effort, time, and money.

At the time of entrance into school a child's concept of health will be largely that of his or her parents, whose knowledge of health matters will depend upon their previous education, the extent to which physicians and nurses with whom they come in contact take time to explain and teach, what their friends say, what they learn from their religious experiences, what they read in books or periodicals, and the extent to which they are influenced by advertising. Though in some instances the health knowledge and practices of the parents may be excellent, in general this disorganized approach to health education tends to produce much misinformation and to perpetuate it.

The home environment, which is determined by the parents and their adjustment to each other and to life, is the strongest single force regulating the degree to which children attain mental and social well-being. In some instances this environment will deter or even prevent the development of mental and social well-being; in others well-being will be furthered, but almost without exception some improvement in even a good home environment will result directly or indirectly from well-organized health services in the community and in the school.

### HEALTH SERVICES IN THE COMMUNITY

Every community has health services of some sort even if they are only those of the police and fire departments. The degree to which the health and health services of a community are developed depends upon the interest of the adult population. The health conditions and facilities of the community have a direct effect on the school-age child particularly in such areas as environmental sanitation, control of accident hazards and housing. There is also an indirect effect, depending upon the degree to which parents utilize such resources as physicians, clinics, hospitals, etc. All too often is it only through the efforts of the public health nurse visiting in



the home that parents make use of existing health facilities, which may be anything from boys' clubs to a prevention-of-deafness clinic or a free hospital bed. The health services in the school are merely part of the health equipment of the community and thus must be oriented to and integrated with the rest. Properly integrated with the home and the community, the school health service can be a major force in the healthy development of the child of school age.

### HEALTH SERVICES IN THE SCHOOL

**General Considerations.** The school, be it private, parochial, or public, offers an ideal place for promoting health through supervisory, educational and clinical services. On the other hand, the school is in such a position that it may affect health adversely, particularly through failing to provide a satisfactory physical and emotional environment for its pupils. Therefore, it is evident that the health of school children must be the concern of everyone in the school, not merely the school nurse or physician.

Promoting health through services in the school cannot be accomplished without considerable cost, nor is it easy to demonstrate clearly the benefits resulting from each dollar spent. For this reason, many look with some skepticism upon the present day efforts to bring school health into a position of major importance. Past experience has shown that large sums of money can be quickly wasted on school health programs which provide rapid screening for physical defects without consideration of the "whole child" and without proper follow-up to assure correction of the defects which are uncovered. However, a well-rounded, thoroughgoing school health program, which is directed at the "whole child" in relation to the home and the community, and includes careful follow-up, is worth every dollar spent, provided we believe that the world will be what the children of the next generation make it, and see clearly the many ways in which the school, in its particularly strategic position, can act directly (and also indirectly through influencing the parents) to further the healthy development of the child (Chisholm, 1948) and the child's ability to live harmoniously in a changing total environment.

The school health services will benefit many of the pupils by providing medical supervision for those children who will receive little, if any, at home because their parents: (1) have insufficient health knowledge, (2) cannot afford adequate medical care or need help in availing themselves of existing low cost medical care facilities, (3) are insufficiently aware of the value of health to be willing to spend money to promote it, or (4) are unable to persuade their children to accept a diagnosis of illness and its treatment, a circumstance encountered most often in respect to dental caries.

Any or all of the pupils may benefit as a result of routine health examination (history and physical examination) carried out every few years, which always uncovers some children with unrecognized remedial conditions of ill health. With few exceptions parents are helped by some degree by counseling and guidance which usually accompanies or results from routine health examinations of their children. Such guidance may also be offered as a result of the teacher's observation of the children, quite apart from routine medical appraisals. By keeping all school personnel health-minded through a well-rounded and active health program, the school

*can improve the well-being of all its pupils regardless of socio-economic status*, for it will be the alert teacher who most often notes individual deviations from good health in the pupils and acts to effect correction of the condition, be it of a physical, mental, or social nature. Just as the teacher is a key person in the detection of ill health, so is he or she of paramount importance in maintaining the health of the physical and emotional environment of the school both through actions and example. It is probable that the future will show us that the school is indeed the most logical and convenient place for providing the coming generations with useful, up-to-date health information, given as far as possible before the children acquire incorrect or outdated notions in this respect from home or outside sources.

Many authorities feel that the optimum in medical care is that given by a single physician throughout a person's life, with referral by him to specialists as indicated. This theory has many pros and cons, and a discussion of it is not relevant at this point. The fact must be recognized, however, that in reality very few people are satisfied with or able to utilize the services of a single physician throughout life. Their dissatisfaction may be due to a change in their feeling of unequivocal acceptance of the physician and his ability or due to a change in geographical relationship, one or the other moving to a distance which makes continuance of the relationship inconvenient or impracticable. Objections have been raised to school health programs on the grounds that routine health examinations, if carried out at all, should be a function of each child's private physician, who knows the child's history and who will understand the child better in illness if he has had contact with him when well. The advantages of having the child's private physician carry out routine health examinations must be balanced against such factors as the willingness and ability of the family to pay a private physician for such services and the lack of interest and training of so many physicians in well-child supervision.

Many schools object to referring routine health examinations to a private physician because his report to the school people following the examination adds very little if anything to their knowledge of the child. This objection can be avoided if the private physician is supplied with an adequate but simple report form with instructions for its use and a statement to the effect that the information thereon will be treated as confidential by school personnel. In addition, the private physician should be informed in advance by the school health service of their observations and opinions of the child. Thus a multiplicity of records and additional clerical time will have to be used to make the interchange of patient information between private physician and school comparable to that between school physician and school.

However, the private physician working in his office or the clinic physician working in a clinic cannot influence the over-all school health services the way the personal contact of the school physician with the school personnel does. Some rather tangible benefits to the health mindedness of the school personnel and of the physician himself will accrue from the work he and the nurse do in the school together with the teachers.

Some school systems have taken the stand that it is preferable to have a school physician examine all the children, referring only those found to have health problems to their private physicians for treatment; others have taken the opposite stand by having no school physician and referring all routine health examinations and children thought by the teacher to be in ill health to the private physician. Between



these two extremes is the presently more acceptable practice of requesting parents to take their children to their private physician for routine history and physical examination, but of further stating that if they are unable or do not desire to do this, the child may be examined by the school physician. This practice provides the parents with a choice in the matter as well as insuring adequate health examinations for children whose families are financially destitute. Any children found to be in need of medical care are, of course, referred to their private physician or clinic of choice; thus, an active health service in the school sometimes refers more patients to private physicians than they can accept.

**Administration of School Health Services.** School health services in this country vary greatly in structure and extent since there has been almost no consistency in the methods used or the goals desired in organizing them whether at city, county, or state level. In general, the health program has been considered as limited to the activities of the school physician, school nurse, and physical education teacher, but is now gradually being recognized as extending to all parts of the total school program.

Health services of private and parochial schools will not be discussed separately as there is no apparent reason to consider the health needs of the children in these schools as differing appreciably from those of the public school children. However, health services for secondary schools do differ from those for the elementary due to the fact that the secondary school is usually departmentalized, which structure results in a tendency of faculty members to emphasize the teaching of specific subjects rather than the over-all well-being of the pupils. Thus, in the departmentalized school the well-being of the pupil often becomes secondary to his or her ability to learn algebra, Shakespeare, and so forth. Pupils transferring to the departmentalized school lose the health supervision which depends upon and results from the day-long contact with a well-trained home-room teacher. Furthermore, school children usually make this transfer at a time when they are feeling the impact of adolescence. It is essential, therefore, to provide high school students with adult advisors or guidance counselors so that there will be someone to whom they may turn and someone who will take an active and unsolicited interest in their over-all health. The other major difference between elementary and secondary school health services is the emphasis put upon having physician and nurse work directly with the high school pupil instead of through the parents, so that the pupil may learn how to assume responsibility for the maintenance of his or her own health.

Administrative organizational patterns of school health services or program fall into four general categories: (1) a joint enterprise shared equally by the departments of education and health; (2) a program run entirely by the department of education; (3) a school health council or committee administering the program and its budget; (4) a program limited to the individual school administered by its personnel with or without the participation of the school's parent-teacher association.

**JOINT ADMINISTRATION BY EDUCATION AND HEALTH DEPARTMENTS.** Administration of school health programs as a *joint enterprise of the health and education departments* is at present the organization of choice to apply at federal, state, county, and city levels. It is usual to have a school health council made up of various interested parties act as an advisory and discussion group for those in the health and education departments who are administering the program. Suggestions and objec-

tions, particularly in regard to health education, may be aired in such council meetings and their proponents offered either grateful acceptance or satisfactory rebuttal.

Some of the reasons for preferring joint administrative structure to administration by the education department alone are as follows:

(a) An agency primarily interested in health and health methods acts as a balance to an agency (the school) which by tradition has been primarily interested in teaching and has not been educated to any great degree in health.

(b) Health departments are not restricted in regard to the type of school to be served by the program, whereas the departments of public education often are permitted little if any activity in private and parochial schools.

(c) The health department is responsible for the health of the people in the community throughout their lives, including the school years, in preventing disease and aiding in medical care and rehabilitation of those suffering its assault.

(d) The health department is in close contact or associated with the various health facilities of the community; thus, it is in a position to know how best to utilize them and can in addition learn from them and from other contacts the deficiencies in health services and health education. For example, evidence of inadequate health education is encountered daily in prenatal clinics and child health conferences, where nurses and physicians encounter the parents' great lack of understanding of nutrition, growth and development, and even of their own anatomy and physiology.

(e) The health department employs public health nurses who have personal contact with the pupils' homes and with many of the community health facilities and who, therefore, can furnish the school with much very useful information. (The school child's health cannot be disassociated from the health of his family or that of the community.)

(f) The health department has the personnel and experience necessary to supervise the nurses and physicians working in the schools.

**ADMINISTRATION OF HEALTH PROGRAM BY EDUCATION DEPARTMENT.** In many areas the department of education administers the school health program without any help from the health department. Occasionally, advice is sought from the local medical society. Such a situation is usually blamed on lack of interest in the program by health department members or on a personality clash in which the members of the two departments find themselves unable to get along. In either instance, all efforts should be made to resolve the problem. Frequently, there is not enough money in the health department budget to pay for a good school health program, whereas the education department has some funds for this purpose. The education department will handle this latter problem better by transferring funds to the health department than by attempting to operate the program alone with resultant duplication of services, at least at the supervisory level, and poor integration with other health efforts in the community. Furthermore, if the education department contributes financially, it has an additional justification for demanding good service.

**HEALTH PROGRAM ADMINISTERED BY SCHOOL HEALTH COUNCIL OR COMMITTEE.** School health councils or committees are sometimes given the authority and budget with which to administer school programs. Such organizations cannot be expected to function smoothly and efficiently, for much of the activities of the program must be through the medium of the health and education departments. In



general, they may act as a middleman in the situation where health and education directors do not see eye to eye, but this same purpose can be served by a *nonaction* group as previously described under joint administration, leaving the health and education departments free to move in direct lines of administration.

The membership of school health councils of either type may include representatives of the medical and dental society, the parent-teacher association, the education department (including "health chairmen," curriculum planners, and/or classroom teachers), the health department, the church (sometimes one each from Hebrew, Catholic, and Protestant groups), the legislative body at the appropriate level, social service and welfare organizations, and sometimes voluntary health agencies. It is not unusual to find the health officer and the superintendent of education or one each of their assistants acting as co-chairman of such councils for a state, county, or city. A council at the community level should consider the advisability of including the community coordinator, if there is one.

**HEALTH PROGRAM WITHOUT DIRECTION FROM SOURCES OUTSIDE THE SCHOOL.** Where there is no direction from higher sources, it should be sought out from city, county, or state level. Good advice and possibly assistance can be expected from the state maternal and child health director or one of his or her assistants. A school health council at the local level of the individual school itself can do much to promote all aspects of health, but can move ahead more certainly and rapidly and encounter fewer pitfalls if given guidance by trained and experienced people. Here again, it is preferable to have the local council one which functions as previously described and not an action group which either dictates school health policies or pays for the program. Such action groups seldom are capable of considering the over-all approach to public health. They are likely to settle on a program in which funds are raised to pay for a school nurse, chiefly for the security of having her present to do first aid and handle emergencies instead of the far more important functions of teacher-nurse conference, home visiting, and over-all health supervision.

### COMPONENT PARTS OF HEALTH SERVICES WITHIN THE SCHOOL

Although closely interwoven one with another, health services in the school may be divided into at least three parts to facilitate discussion, namely: (1) health of the school environment; (2) supervisory, screening, and clinical health services; and (3) special services including health education. It is not uncommon to find the term "school health program" used in the more narrow sense to designate only the clinical, screening, and supervisory services.

**Health of the School Environment.** The health of the school environment is made up of two component parts—the physical and the emotional. Neither part can be neglected, for both have a strong influence on the health of school children. Unfortunately, however, defects in the physical plant of a school are usually much more obvious than defects in the emotional content, and thus there is a tendency to appropriate funds for building new schools or remodeling old ones without making comparable efforts to supply a thoroughly healthy emotional environment for children. Although a good physical plant has definite value, a really sound emotional environment offers far more lasting health benefits to the child than does the physical.

lege of attending a school which incorporates the latest advances in architectural design, interior decorating and equipment.

**PHYSICAL ENVIRONMENT.** Avoidance of health hazards is of primary importance in the design of the school plant. The school site should be located away from noise, smoke, odors, and fumes. The acreage should be generous to permit large outdoor play and athletic areas as well as pleasant landscaping. Traffic hazards are to be carefully avoided but not to the point of sacrificing accessibility to public transportation (American Association of School Administrators, 1949).

The exterior and interior of school buildings when well designed are now inviting and cheerful, in contrast to the forbidding exteriors and the stern and often dim interiors formerly considered appropriate for schools. In the classroom a floor area of 25 to 30 square feet per pupil is recommended. Recreation and lunch areas are placed and equipped in such a manner that they may be accessible and useful after school hours to adults, the idea being to encourage the use of the school as a center of recreational as well as educational activities in the community. Construction is planned to minimize fire hazards and such accidents as falls down stairs and in corridors.

Special consideration is given to lighting (Hamon, 1948), interior decorating, acoustic treatment and equipment. Wall and ceiling finishes are chosen to give optimum lighting with minimum glare from shiny surfaces and to keep brightness difference \* within a comfortable ratio, still preserving enough color contrast and variation to avoid monotony. Floors are finished in as light a color as practical and constructed with the idea of maximum durability without creating a slippery surface. Prismatic glass block is used in many school buildings to obtain maximum use of natural lighting without glare or the need for shades. Artificial lighting, with louvered fluorescent or incandescent fixtures, is designed to give a minimum of 25 foot-candles in the darkest corner. No one has as yet found a mechanical device to solve the problem of improper use of lights and shades by the classroom teacher. Each teacher should know the essentials of good lighting, but it is often advisable to have the school custodian make routine inspection of classrooms to serve as a reminder to the teacher to pause long enough to take note of the light, temperature, and humidity in the room.

Some of the changes which are being made in classroom equipment include the use of green glass chalk boards and of light color furniture finishes to avoid excess brightness difference, both in respect to the paper or book on the working surface of the desk and to the light finishes of walls, floor, and ceiling. The tendency at present is to use movable, table-type desks in elementary schools, thereby permitting special groupings for recitation, and other variations in the arrangement of the room. All ceilings should be acoustically treated to maintain a minimum level of noise without the need to suppress the normal enthusiasm of school-age children.

The heating, ventilating, and humidification equipment for schools is designed to produce classroom temperatures of from 68° to 72° F, the reading being taken

\* Brightness difference—"the difference in brightness among the various reflecting surfaces and light sources within the total visual field as measured in foot-lamberts. Optional terms: Brightness contrast, such as the brightness difference between white paper and black print, brightness ratio, the brightness difference between the visual task and the surrounding field." "Lighting Schoolrooms," Pamphlet No. 104, Federal Security Agency, U. S. Office of Education, 1948.



30 inches above the floor, and a relative humidity close to 50 per cent. Here again, in addition to possible mechanical difficulties, the problem of the human control factor is encountered, particularly in the avoidance of excess heat. The person responsible for regulation of ventilation must keep in mind that a classroom which has a temperature of 70° F when the pupils enter it may soon be excessively hot, due to the heat radiated from the bodies of its occupants. Fifteen cubic feet of air change per person per minute is generally considered adequate to prevent staleness of air and accumulation of body odors.

Plumbing fixtures, such as drinking fountains, sinks, and toilets, should be chosen according to the size of the children who will use them, particularly in elementary schools. The proper maintenance of washrooms which includes an adequate supply of soap, towels, and toilet tissue is of great importance to the teaching of health habits or personal hygiene. Tooth brushing equipment, however, may be kept in his desk or locker. Locker and shower rooms should be designed to be comfortable in regard to space, temperature (75° to 80° F), lighting, and odors, as well as practical from the standpoint of maintenance and cleanliness. There should be at least two toilets in each general toilet room. Roughly, one toilet to 30 to 45 girls and one to 60 to 90 boys is considered minimum (American Association of School Administrators, 1949), provided boys' toilet rooms are also equipped with urinals.

Last, but by no means least, the well-designed school building has facilities for teachers, so that they can rest, smoke, converse, and in general get some respite from the constant pressure of the classroom.

The foregoing paragraphs describe a physical school environment which is highly desirable but not always attainable, particularly when funds are sufficient only for the rehabilitation of existing structures. Some reconditioning of old school buildings is usually worth while when the community cannot afford needed new construction. Often a small expenditure for materials such as paint and light fixtures is all that is needed for an enthusiastic parent-teachers group to transform dingy, drab schoolrooms and corridors into a cheerful, well-illuminated environment for their children.

**EMOTIONAL ENVIRONMENT.** How healthy the emotional environment of the school is depends largely upon the degree of physical, mental, and social well-being of the personnel. The personnel includes everyone from the janitor to the principal but it is the classroom teacher, more than anyone else, whose attitudes determine the emotional environment most directly affecting the pupils. The total well-being of the teacher involves many factors. Among these, the influence of the principal on the happiness which the teacher derives from working in the school cannot be overlooked, for there is a strong feeling among school people that the teacher should follow the lead of the principal. Thus, conflicts may often arise, despite good health in the teacher, if the principal is poorly trained or emotionally immature.

Long range planning for improving the emotional environment of public schools must take into account, first and foremost, the need for raising the prestige and the salary scale of school personnel. At present, there is still too great a tendency for people to gravitate into teaching simply because they have no specific desire for other occupations. Public school teaching must be given the status of a career—a career which is considered to be of the utmost importance to humanity. Also

with the giving of status there must be a salary scale which will not only permit but will attract highly qualified men and women to choose this career. There should be no rules forbidding employment of married women in teaching positions, but instead, rules providing for removal of teachers who show themselves repeatedly to be emotionally immature, and thus obviously unable to guide children toward the attainment of mental and social well-being. If there is any one aspect of greatest single importance in the contribution which public schools can make to child health, it is that the teachers be people who are well adjusted in their own lives, who have good physical health, and who have had thorough training in education including specific training in health education. They need also to believe in the inborn desire of children to love and be loved, to imitate and to cooperate with their elders. The belief that children are by nature uncooperative, spiteful, and sinful leads to an approach based on rules, regulations, and punishments, all designed to rid the child of his or her unfortunate heritage. The person who believes in such an approach to children should never be trained or employed as a teacher, for a child's reaction to such treatment will almost surely be one of anger, frustration, and a desire to "get away with" antisocial activities.

**ENVIRONMENTAL CONSIDERATIONS FOR EXCEPTIONAL CHILDREN.** The term "exceptional children" is used to designate those children who for any reason deviate from the usual to such an extent that special adjustments in their environment and management are indicated. Thus, such a child may be too brilliant or too dull to get along well with the rest of the group, may have impairment of vision or hearing, may have a cardiac or an orthopedic handicap, may be hospitalized for chronic illness, may be emotionally too insecure to join a large group, or may be merely a poor reader and unable to keep up with the pace set by the majority.

Whatever the disability, special arrangements must be provided for these children so that they will have suitable opportunities for health and education (Mackie and Fitzgerald, 1949; Loviner and Nichols, 1946; Education Briefs, 1948). Such arrangements may take the form of anything from special schools to simply special classes which meet only occasionally. In general, it is highly desirable to keep the education of exceptional children within the framework and the actual building of the regular public school, thereby giving these children the chance to mix with others of their own age group and to learn how to get along. Children who attend a special school throughout their schooling period are often at a disadvantage when they graduate and are forced to face an unsheltered existence in the community. For this reason, the present trend is to equip all new multistoried school buildings with elevators for those who cannot climb stairs and to provide some schools with special teachers and facilities for sightsaving classes, for instruction of the hard of hearing, for physiotherapy for children with orthopedic problems including cerebral palsy, and for "ungraded" or "opportunity" classes. Speech and reading difficulties are so common that it is more practical to provide speech and remedial reading teachers to all schools on a part-time basis, each serving several schools within a city or county.

The education of the child with epilepsy deserves special consideration. In many areas the child known to have epilepsy is denied entrance into the public school system and often no other provision is offered for his education. The majority of children with epilepsy can be well controlled with proper medication, and thus given the same educational opportunities as those free of this condition. Thus, the first



step in making public school education available to the epileptic child is that of procuring the best possible medical management of his disease. Of those children whose seizures are not completely controlled by medication or removed by surgical intervention, a small percentage will have to be institutionalized, but there is a remaining group of children who should not be denied entrance into public school, because of occasional convulsive seizures. Parents and teachers alike must be brought to realize that the occurrence of a seizure in a child in a classroom need not be considered as a detrimental experience for the other pupils (Yahraes, 1947). Such an episode, when properly handled by a teacher who has been forewarned of the presence of the condition, will not result in severe emotional disturbances in other pupils who are present.

When circumstances are such that a special class is the best answer to the need, every effort must be made to return the exceptional child to his group as much as, or as soon as, possible. School administrators must guard against regulations which demand a specific attendance level in special schools or classes, for such regulations may prolong an individual child's presence in such groups unnecessarily. The teacher who knows that the class will be abandoned if there are less than 15 pupils in it naturally hesitates to return the fifteenth to regular class, thereby losing this benefit for the other 14. However, for the most part, obtaining funds to provide special equipment and special teachers for children with demonstrable physical handicaps is relatively easy as compared to obtaining sufficient funds to provide those classified as normal with an environment conducive to complete health.

**Supervisory, Screening, and Clinical Health Services.** There are, and probably always will be, some children enrolled in public schools who have had little if any health supervision. In addition, there are many instances in which well-trained teachers recognize deviations from good health in children who have had the benefit of fairly adequate health supervision. The school offers an extremely convenient and inexpensive place to carry out immunizations and screening procedures. Screening programs for vision and hearing constantly uncover unsuspected impairments of these special senses. In addition to these reasons for establishing adequate health supervision in the schools, there is the added advantage that such supervision in the school can be given by people who are in a position to be far more objective in their judgments than parents can be and can relate a child's social and emotional adjustment to that of his peers, whereas parents must first relate these adjustments to their own immediate family. The school nurse and the home-room teacher are in particularly strategic positions to carry out the follow-up so important in obtaining correction of illnesses and abnormalities which have been discovered in children. It is not unusual to find that it is the teacher, not the doctor, who has persuaded a parent or a child to carry out the medical or dental recommendations.

Schools which have no clinical, screening, or supervisory health services should be properly prepared before these services are organized. First and foremost a need for school health services must be recognized by the department of education, the teachers in any individual school and the parents. Once it has been agreed that health services are needed (a need which is probably universal but often unrecognized until pointed out by public health groups) the education and health departments usually can move ahead rapidly with plans to supply them. One cannot overemphasize the importance of including in the planning representatives of the

appropriate medical and dental societies and of the school or schools to receive the services. Ophthalmologists and otolaryngologists who practice in the community should be consulted if vision and hearing testing programs are to be organized. Within the education department, those responsible for curriculum planning are essential members of any group working out details for school health services.

An effective approach to the actual initiation of the supervisory, screening, and clinical health services within a school or group of schools is through the medium of a *school health institute* at which the program is explained, a demonstration *teacher-nurse conference* between a classroom teacher and a public health nurse is given and a pediatric history and physical examination are carried out using one of the pupils in the school as the patient. Following this introduction, *teacher observation cards* \* are distributed and the public health nurse begins her duties, full or part time, as the school nurse. If the program is to include a school physician he should not start working in the school until the nurse has had an opportunity to do the groundwork.

**Supervisory Health Services. TEACHER OBSERVATION AND TEACHER NURSE CONFERENCE.** The key figure in the present day school health program at the school level is the teacher—particularly the home-room teacher in the elementary school. The teacher's importance to the promotion of the health of his or her pupils cannot be overestimated. Through careful observation, the teacher can pick out very nearly all children with significant deviations from physical, mental, and social well-being, help to correct some of these by giving special attention to the child and his family, refer others for help, and follow up those referred in order to be sure that the needed help has been obtained. Besides being the person in the best position to note deviations from health in the pupils, the teacher is the person upon whom the health of their physical and emotional environment will depend most. The extent to which the children are taught to appreciate physical, mental, and social well-being also depends largely on the teacher. Obviously, many teachers do not have adequate knowledge with which to promote health in the various ways which have been outlined. It is imperative, therefore, that those now in training to become teachers be given the best possible courses in health supervision and health education and that similar opportunities for such education be supplied to teachers in service (Wheatley, 1948).

A great deal of health education can be supplied to the teacher who is in service through the introduction into the school of a school health program. The teacher who attempts to make objective observations of her pupils and discusses these with the school nurse soon discovers how much health information he or she has gained. It must be emphasized that the teachers should observe and later discuss in the teacher-nurse conference *all* of the pupils in the classroom, not merely those with obvious abnormalities. A conference about all the children in the class is essential to give both teacher and nurse a clear concept of what may be considered normal for the group and to give the nurse an opportunity to suggest instances in which minor

\* Teachers should have a record card for each pupil on which to record their observations of the pupil's health. This record card should be a form which permits chronological notes to be made at any time and which lists some of the items which are considered important to good observation of the well-being of each student. Uniformity of such record forms can be accomplished if the state department of education has them printed and supplied at cost to the various schools.



abnormalities may have been missed. The results of teacher-nurse conferences should be education of the teacher, education of the nurse in the problems confronting the teacher, and definite plans for correction of health defects which have been brought to light. Using the information gained, the nurse may move ahead to obtain more pertinent information from contact with the home or from medical records or to help parents arrange for medical, dental, or psychiatric care as indicated. *Referrals from teacher-nurse conference to the school physician should be given priority over all other health examinations.* Finally, opportunity must be provided for the nurse to keep the teacher posted on the progress of those children considered in conference to be in need of further investigation or medical care.

**PRESCHOOL ROUNDUPS.** During the spring, some schools ask parents to bring to school for an introduction those children who will enter first grade in the fall. The purpose of this visit is to acquaint the parent and child with the school, the principal, and the first grade teachers, and vice versa, and as such is highly commendable. Unfortunately, some school systems use this opportunity to have physical examination carried out and immunizations given. The introduction of a five- or six-year-old child to a school certainly is not made easier by giving him injections. Such procedures are to be condemned. With the exception of the referrals from the screening done by the teacher, and or school nurse, physical examination and correction of physical defects are better postponed until after the child has entered first grade and some time has been available for teacher observation.

**Screening.** In addition to the all-important screening which is accomplished by teacher observation, certain other types of screening are strongly advocated for use in schools. Such screening includes the usual psychometric examinations, reading readiness tests, vision testing, hearing testing, and height and weight measurements. It is recommended that evaluation of the interest level and of the emotional maturity of each child be considered as a source of information which can be most useful in guidance and counseling. With the exception of hearing testing and the more complicated psychological examinations, it is felt that the types of screening mentioned above can be carried out by the teacher and can be used as aids in teaching health as well as being an educational experience for the teacher.

**VISION TESTING.** That some sort of routine vision screening examination is indicated is obvious from the report of the study conducted in St. Louis, Missouri (Children's Bureau Publication Number 345, 1954) in which 26.9% of 606 first grade and 609 sixth grade school children were found to be in need of eye care. Children of elementary school age seldom recognize the presence of subnormal vision and often become the slow students and daydreamers of the class without anyone realizing that they cannot see as well as their classmates. As aforementioned it is entirely possible and thoroughly desirable to test the vision of every pupil annually as part of the school curriculum. In the elementary school, the home-room teacher is the person of choice to carry out the testing; certainly teaching the younger children about vision, eye care, vision testing, and the use of the "illiterate E" is the function of the teacher. Vision testing in the high school is more often allocated to the school nurse (National Society for the Prevention of Blindness, 1945). Carefully trained volunteers, usually parents, may do vision screening at any grade level but failures should be checked by the school nurse before referral to ophthalmologist.

The teacher's observation of the pupils for signs of eye disease and poor vision

The teacher's observation of the pupils for signs of eye disease and poor vision is a very valuable case-finding method whether or not vision testing is done routinely. Teachers should be reminded repeatedly that children who have passed their vision test are none the less subject to eye disease and should be referred for ophthalmologic diagnosis without fail should they be observed to exhibit signs and symptoms suggestive of eye trouble.

Two problems which have arisen in connection with vision testing are: (1) the type of equipment which should be recommended, and (2) the objections raised by ophthalmologists that schools refer too many children who, on careful examination, prove to have normal vision.

When the first problem is encountered, it is best settled by consulting the Council on Physical Medicine of the American Medical Association. Of the many testing devices available, the Snellen Test Chart and the Massachusetts Vision Test Kit have been the only two types of equipment which have been approved in the past. Data accumulated by the aforementioned study of vision testing conducted in St. Louis indicate that the more complicated testing equipment, though finding the greatest percentage of those needing referral, triples the time needed for administering the tests and results in almost twice as many incorrect referrals as compared with the Massachusetts test or the Snellen (high standard) combined with careful teacher observation. Whatever type of testing device is chosen by a school or school system, instructions for its proper use should be closely adhered to. Particular attention must be paid to proper lighting of the chart surface (10 to 20 foot-candles) and to placing the reading material at the proper distance from, and height in relation to, the pupil being tested. Vision testing is best carried out in an area which is quiet and adequately illuminated. The teacher administering the test should be thoroughly familiar with the procedure and the pupil being tested should receive prior explanation of the test objects and responses necessary. It is recommended that the testing be sufficiently complete to screen out pupils with subnormal visual acuity, farsightedness and muscle imbalance.

The problem of over-referral to ophthalmologists can be met by holding a conference with those physicians who will receive the referrals or with a committee appointed by the local ophthalmological society. Such a group should pass upon the equipment and the referral criteria to be used. It is most important to have all concerned realize fully that: "The average school child who is in need of ocular attention seldom presents himself for help. We must instead search for him. Any good type of screening examination will pick out a majority of those in need of help but it will also single out a large number needlessly and there seems to be no way around this dilemma which exists because of the psychology of the child. Ideally, it is obvious that every school child should have a complete ophthalmologic examination. If only screening examinations are done, generally speaking, we must be prepared to examine completely two children to find one that really needs help" (Scobee, 1950).

**HEARING TESTING.** Hearing testing of school children has disclosed a remarkably high incidence of unrecognized impairment of hearing, figures varying from 5 per cent to over 10 per cent having been reported. As is so often true in cases of subnormal visual acuity, the child with impaired hearing seldom knows that he or she does not hear as well as others, and again the end result often is a child who



becomes inattentive, and falls behind in school work, usually developing nervousness and conduct disturbances concomitantly.

Speech disturbances are commonly found with impaired hearing; whether present in conjunction with subnormal hearing or not, they should be brought to the attention of the school nurse or physician and arrangements made for diagnosis and appropriate therapy (Johnson, 1948).

Prevention of deafness programs are turning to the school as the best possible place to carry out routine audiometry of school-age children. The problem of finding a room in the school building which is sufficiently quiet for audiometric testing can be met by constructing a portable booth lined with sound-absorbent material which can be taken to any school which the audiometrist designates.

Hearing testing is a procedure which should be done by a trained technician using a pure-tone audiometer (Dahl, 1949) of any make accepted by the Council on Physical Medicine of the American Medical Association. An experienced technician can test the hearing of as many as 45 children per hour using the sweep-check method and later retesting more completely any children failing the sweep-check test. Individual testing of each child is preferred to group testing. The use of the recorded voice test method is not advocated. The practice of appraising the adequacy of hearing by determining the child's ability to hear a watch tick or the examiner's whispered voice is to be thoroughly condemned. Such tests have been shown to be grossly inaccurate. Testing hearing in this way is a waste of time, and, what is more important, represents a serious threat to the child whose hearing is below normal but adequate to hear the watch tick or the examiner's whisper and therefore not investigated further.

Facilities for a more extensive program being wanting, the best practice is to test the hearing of at least the first, fourth and seventh grade pupils routinely and of those referred as a result of teacher observation or school health examinations. The value of screening the lower grades for hearing impairments cannot be over-emphasized, particularly because the marginal hearing loss, if discovered early, is more likely to prove to be amenable to correction (Crowe and Burnham, 1941; Davis, 1947). But even if the hearing impairment cannot be corrected, the child will benefit from having his disability known and appropriate steps taken to minimize its effect whether by use of a hearing aid (Watson and Tolan, 1949) or special training such as lip reading. When people know why a child's ability to communicate with others is below average, they are far better able to modify their approach accordingly.

**MENTAL AGE AND READING READINESS.** Testing of mental ability and reading readiness will not be discussed here other than to point out the importance to the child of being placed in a group with which he or she can keep up. For example inability to comprehend the reading material has been found to be the basis of gross misconduct in many pupils, the conduct disturbance often disappearing when remedial measures begin to reduce the reading disability (Betts, 1946).

**PHYSICAL GROWTH.** Many school systems have some sort of weighing and measuring program. Periodic recording of the height and weight of each pupil can be part of good teaching of growth and development as well as a means of detecting growth failures. For the most part, charts which give the teacher only the limits of normal for height and weight at a given age do more harm than good, parents being greatly disturbed when told that the child is so many pounds or inches below the

normal for that age. Growth curves used to portray each individual child's rate of growth graphically are preferred. Forms for recording growth curves are exemplified by the "Physical Growth Record for Boys" and "Physical Growth Record for Girls" of the National Education Association (Joint Committee in Health Problems on Education) and the American Medical Association and by the Wetzel Grid (Wetzel, 1942). Such records give the teacher, child, and parents the opportunity to follow the individual growth pattern. Deviations from the expected rate of growth as individually determined can be taken as indicative of some disturbances in the child's health and thus serve as an acceptable reason for referral for medical opinion. Some school systems have chosen the Wetzel Grid as preferable to other types of growth curves because the graph represents a composite of height and weight, in other words of body size, which is then plotted against age in a second graph to show the rate of growth and compare it to averages for each age level.

**Clinical Health Services.** Clinical health services in the school health program divide roughly into diagnostic and therapeutic, medical, and dental.

Dental services are provided as a part of maternal and child health programs in many states, usually in connection with programs for children of school age but occasionally through child health conferences. Though still very inadequate in many areas, school dental programs are growing as efforts increase to: (1) reduce the incidence of dental caries through teaching good dental hygiene and applying sodium fluoride (Easlick, 1949), and (2) to preserve teeth already affected by systematic and prompt filling of the cavities. Federal funds budgeted in 1949 to promote these purposes under Title V of the Social Security Act were about \$800,000 to which may be added a somewhat larger amount of matching funds. Some of these funds were used at various dental schools to support graduate training in dentistry for children and also to provide refresher courses in this subject for practicing dentists.

Some school dental programs are limited to those children who cannot otherwise afford dental care, while others have no limitations and provide prophylaxis, fillings, and extractions for all; they seldom include orthodontic procedures. The program may offer dental care without cost or at cost, the former usually being the type restricted to children with insufficient funds. It is usual to start the program in the lowest grades and expand it by one more grade each year. In this way the amount of dental correction necessary in each grade included in the program is kept at a minimum. In view of the fact that in this country one may expect at least one new carious surface per year in about 98 per cent of the population, it seems wasteful of professional time to do dental inspections. Thus, it is preferable to have inspections carried out as part of prophylaxis or treatment except when it becomes necessary to give the parent an estimate of the amount of dental work needed and how much it will cost.

The school medical program is usually limited to the work of a part-time school physician with the help of a full- or part-time school nurse. It is desirable to have the school personnel feel that these two people are faculty members with interest in the "whole child" including his or her education. The school nurse and physician have much to contribute to the health of the school environment provided they are made to feel that they "belong"; when treated as people who should "keep their noses out" of education, their contribution will be slight.

Very little therapy is attempted in school medical programs other than first aid. There are some conditions, however, which are so frequently encountered in school children that one wonders if treatment of them might not be justified. Such condi-



tions include acne, epidermophytosis, impetigo, scabies, postural defects, and fallen arches. Then, too, there is the question of whether or not the school might be an ideal place for guidance and counseling of children and their parents in the management of some of the milder emotional disturbances which cannot be referred to overcrowded mental hygiene clinics and overworked child psychiatrists. The school health service as a medical care program is presently being investigated in some areas as a possible answer to assuring correction of abnormal conditions uncovered as a result of teachers' observations or routine health examinations.

**THE HEALTH EXAMINATION.** History and physical examination of well children will not be discussed in detail. Suffice it to say that the history should be extensive enough to provide a general picture of the child's health, past and present, a brief review of systems, some insight into the present health and economic status of the family, and a rough idea of the child's habits and personality. The physical examination should omit vision and hearing testing, provided these are being carried out as screening procedures, and examination of the chest should concentrate on the heart. Laborious examination of lungs is of very little value, and chest x-rays are relatively easy to obtain.

The child should be stripped at least to underwear shorts, and a short gown provided for older girls to avoid embarrassment. The physician's impression of the child's general appearance, posture, and state of nutrition is most important and should always be recorded. Many feel that abdominal palpation is worth the few minutes it takes, and cardiologists consider palpation of femoral pulses valuable. Taking of the pulse before and after exercise is probably of very little value. Examination of ears with an otoscope sometimes uncovers significant abnormalities of the outer ear or drum. Ophthalmoscopic examination of the eyes is of value only if done by an ophthalmologist as a screening procedure—the amount a school physician can discover by a brief inspection of the retina without dilatation of the child's pupils is hardly worth the time consumed in darkening the room and showing the child how to keep the eyes fixed on a distant object. The spine and musculo-skeletal structure, particularly of legs and feet, should be examined. Older children should be checked for epidermophytosis. There is a general feeling that the genitalia of older girls should not be examined, at least not by male physicians. This attitude is probably a disservice to girls in that it teaches that this portion of the anatomy is unimportant from the standpoint of evaluating their total health and adds to, rather than detracts from, their reticence to seek medical opinion when abnormal genital conditions arise. The value of examination of the genitalia in the male is unquestioned.

As aforementioned, the home-room teacher usually records height and weight measurements for the pupils in the elementary school. In the secondary school this procedure is frequently delegated to the school nurse, or simply neglected. Whenever the pupil's physical growth is not being followed by the teacher or the nurse recording of the height and weight should be part of the physical examination. Though many physicians consider it a waste of time, taking and recording of the pupil's blood pressure on at least one occasion seems justifiable, and can be done by the nurse whenever this seems desirable.

Health examination of school children can be enhanced by proper preparation of the child for the experience. The teacher, nurse, or doctor can speak with each

class prior to scheduling health examinations to explain that they are merely a visit to the doctor for promoting health and *have absolutely nothing to do with obtaining a passing mark in order to graduate*. The pupils should be encouraged in this and other ways to bring up questions about their own health and ask for interpretation of the findings of the physician. The health examination should not carry with it the threat of immunization procedures, which can better be carried out en masse at another time.

Other factors which will enhance the medical services of the school are:

- (1) Quiet examining room with dressing cubicles which permit privacy.
- (2) Hand-washing facilities for examining room.
- (3) An examining table and standard equipment such as desk, chairs, flashlight, tongue blades, clinical thermometer, etc.
- (4) A school nurse in attendance.
- (5) A rest room with cots for ill children awaiting transportation home *which can be supervised from the school administrator's office when the school nurse is not on hand*.

(6) A small waiting room for parents (waiting should be kept at a minimum) in which health education pamphlets are available for them to read.

**FREQUENCY OF HEALTH EXAMINATION.** The majority of school health programs require periodic medical examination (history and physical examination) of a pupil which may vary in frequency from several each year (for athletes) to a single examination carried out in the first grade and never repeated. Highest priority must be given to examinations requested as a result of teacher observations, and second to an examination of all children at the time of entrance into school. Physical examination before graduation from or leaving school is next in importance.

Repeating a history and physical examination (of the type described) each term for athletes is probably not justified. These pupils are in general the most physically fit in the class and under continual observation by the health and physical education teacher who should be far better prepared than most on the teaching staff to note signs and symptoms of illness in the student group. However, the fact that some physical education teachers are not well versed in health supervision and the fact that some coaches of major interscholastic sports concern themselves only with winning games cannot be overlooked. To safeguard the health of pupils engaging in strenuous physical education activities and competitive sports, there must be regulations preventing them from returning to the activity or sport following an injury or major illness without written permission of a physician. Teacher observation of the pupils' health and teacher-nurse conference must be considered an indispensable part of the activities of physical education teachers. Brief history and physical examination of athletes at the beginning of each season can be used as an additional means of screening out those who have residual disabilities from injuries received while engaging in sports during the previous season or from illnesses which have occurred since the previous physical examination was carried out.

A relatively complete history and physical examination of each pupil, carried out about every three or four years throughout the 12 years of schooling, is considered to be a worthy objective, if annual physical examination is impossible. But widely spaced health examinations are the method of choice only when teacher



observation can be relied upon to cover conditions of ill health which occur in the intervening years.

**FOLLOW-UP.** There is, of course, almost nothing to be gained by uncovering conditions of ill health if their correction is not possible, whether due to lack of facilities, lack of family funds, or failure to make recommendations clear to parents and then check back to be sure that the desired action has been taken. Thus, if there is no way to obtain correction of the defect, the discovery of an impairment of vision or hearing has its only value in a better understanding of the child's slowness and a better classroom seating arrangement for him. First of all, facilities must be available within or near the community to meet the demand of referrals of health problems from the school—another important factor in favor of active health department participation in the program. If the health services of the community are inadequate to the demands of school referrals, the health department must take the steps needed to correct the situation. Provided the community has the needed services, the next consideration is that of making them available to every child regardless of race, creed, color, or economic status. There then remains the job of working with the child and his parents so that they will avail themselves of the needed services—a task which can be very time consuming and frustrating. Here again the team of teacher and nurse is most effective, for, if both work toward the same end, these two members of the school staff are the ones who can most often influence the child and or the parents to obtain the recommended care. It is well for both teacher and nurse to keep a follow-up record of the children so that both can strive continually to have the child's needs met.

**THE SCHOOL PHYSICIAN.** The school physician usually works on a part-time basis and is present in the school for a certain number of hours or mornings each week. The physician should plan to work at the school at regular intervals throughout the school year rather than to attempt to complete his or her work within a few weeks time and move on to another school, leaving the first school without medical consultation for the rest of the year. Regardless of their previous training it is well worth the effort to provide a series of seminar discussions to acquaint physicians who are new to the program with its intent and procedures and to follow these with occasional meetings of the doctors in school service in order to keep them up to date on new developments and to add interest to their work. Many physicians who have had all their previous experience with ill children can testify to the knowledge gained in regard to history and physical examination of the well child by participation in such discussions. The purposes of the history and physical examination as carried out in the school are: (1) to obtain an opinion of the total health of the child which will help school personnel and parents to understand and guide him or her as wisely as possible; (2) to uncover unsuspected deviations from normal; (3) to obtain sufficient information concerning deviations to be able to refer the child to a private physician or clinic for further medical care and to plan medical care with the parent. Both physician and nurse should strive constantly to make the total experience an educational one for the parents and child.

The presence of the parent at health examinations of elementary pupils is of extreme importance. For the child who is in high school, it is felt best to invite the child to bring the parent if he or she wishes to, the emphasis then being on promoting the child's own ability to supervise his or her own health. Health exam-

inations of this type cannot be carried out in 5- to 10-minute periods; school physicians must plan for at least 20 minutes per pupil and must realize that often this period needs to be extended when problems in guidance and counseling arise. Probably the best procedure is for the school to notify the parents that the child should have a health examination and to request their approval of having this done in the school if they do not wish to take the child to a private physician for it. Once the parents have signified their desire to have the examination carried out in the school, an appointment should be made either with the child in the upper school or with the parents of children in the first seven or eight grades for a specific time and day for the examination. The appointments with parents should be far enough in advance to permit them to choose the most convenient time and date.

The school physician, in addition to carrying out health examinations, must be the liaison person between the school and other private physicians in the community. He is in a position to check with private physicians when they make special requests for modification of school curriculum for health reasons and is also in a position to push for good medical care of the children referred to private physicians and clinics. The value to the total school health program of having a school physician has been discussed.

**THE SCHOOL NURSE.** As aforementioned, a public health nurse is considered to be the best person to act as school nurse. The importance of the nurse to the school health program is second only to that of the teacher. By attending health examinations carried out in the school, the nurse can know firsthand just what the physician's recommendations are, and can be most helpful to the physician, parents, and child in planning whatever medical care is indicated. By visiting in the child's home, the nurse can obtain valuable information for both the teacher and the physician. The conferences between the nurse and the teacher have been described as being of educational value to both, as well as important to the total health of the children. School nurses should be considered as faculty members, and their knowledge of health matters and the health status of the pupils recognized as an important source of information to teachers and students alike. It is hoped that schools will recognize the true value of the nurse as aforementioned and avoid forcing her to use up her time performing such duties as simple first aid to scrapes and bruises, acting as a diagnostician of rashes, abdominal pains, etc., which should be immediately referred to the family and their physician, and doing the clerical work of arranging transportation home for ill children.

**SCHOOL HEALTH EMERGENCIES.** The most important single factor in the handling of health emergencies arising in the school is to know how to contact the parents. Every school administrator should keep an up-to-date file for every pupil which supplies the following information: (1) how to contact the parents at any time; (2) how to contact some other responsible person if unable to get the parents; (3) the name and address of the private physician of choice; and (4) name and address of the hospital of choice. Every effort should be made to have some one or two members of the school staff trained in the principles of first aid, but the rule should be one of "hands off" as much as possible, with the emphasis put on notifying the parents. Simple first aid for cuts, scrapes, etc., should be carried out as far as possible by the classroom teachers, and for this purpose classrooms should be



equipped with first aid kits. Minor injuries of this nature when handled within the classroom can represent a health education experience for the entire class.

**RECORDS.** Forms for recording teachers' observation of the pupils' health have been discussed previously. The results of hearing and vision screening and height and weight measurements should be recorded either on the teacher observation record, on separate records, or on the pupil's medical record. All such records should be brought with the child whenever he or she is referred to the health suite.

Several other record forms must be considered as important to the school health service.

The aforementioned form for the use of the private physician when carrying out health examinations in his office must be self-explanatory, brief, and to the point, but must request sufficient information to give the school a clear, concise picture of the child's total health status including historical and physical findings.

The information necessary to the proper handling of school health emergencies, as discussed in the preceding section, is best kept on a specific form. The most important detail in the use of this form is that it be brought up to date at the beginning of each semester.

A master chart for recording the activities of the health suite is often very helpful in keeping track of cases needing follow-up and in making reports of the number of children seen, the findings, and the degree to which those running the program have been able to initiate steps for correction of conditions of ill health.

The school physician must have a separate form for recording the history and physical examination of each pupil who receives a health examination at the school. This form should be designed to contain as little changing information as possible—addresses, occupation of parent, etc., are better kept on a separate form filed with the rest of the academic record. The record should contain the name, birth date, sex, and race of the pupil, the names of the parents or guardians and the names and year of birth of siblings. The name and address of the school of attendance should be recorded and space permitted for changes in these. A section is usually provided for filling in the record of immunizations (initial and booster doses) and of acute communicable diseases. A small space is often provided in which to indicate the whereabouts of additional information of a nature too confidential for inclusion in the record. A check list is desirable as a means of saving the physician's time and as a place where those responsible for follow-up can tell at a glance what is to be done. A code may be used in conjunction with the check list to indicate positive findings and whether follow-up, observation, or mere recording is indicated. It is well to request physicians using the form to indicate also when specific items of history or physical examination have been omitted. For example, it is quite common to omit examination of the genitalia of older girls. When this is the case, the check box should be marked "N.E.," or with some symbol standing for "not examined," rather than leaving it blank or marking it "O" or "Neg." Suggested items for inclusion in the checklist are given on page 699.

The remainder of the form is best devoted to lined space for notes written in chronological order, not only by the physician but also by the nurse, guidance counselor or whoever has pertinent information to contribute. A wide, left-hand margin permits the recorder to write his or her name and title, the date, and the nature of the note to the right, such as "health examination," "teacher-nurse referral,"

## HISTORY LEADS

Date  
 Grade  
 Parent present  
 A. Development  
 B. Illnesses  
 C. Operations and injuries  
 D. Current illness in others in household  
 E. Familial diseases  
 F. Health habits  
 G. Living conditions

## PHYSICIAN'S FINDINGS

1. Summarize in your notes at each examination your impression of this child's total health—physical, mental, and social well-being
2. Skin
3. Ears
4. Eyes
5. Nose and throat
6. Mouth, teeth
7. Heart
8. Chest
9. Abdomen
10. Genitalia and hernia
11. Posture and extremities
12. Neurological and psychiatric, including convulsions
13. X-ray and laboratory
14. Blood pressure
15. Normal femoral pulsation present—  
 Yes ☐; No ☐

“parent-physician conference,” etc. The calendar months are sometimes printed along one edge when the record is in card form as a convenience to those wishing to use metal tabs for flagging.

The committee which recently revised the pupil's medical record for the state departments of education and health in Maryland outlined the following principles for its use:

- (1) The record should be considered as highly confidential by all school personnel.
- (2) It should not contain information which might be detrimental to the child, as the record follows him or her throughout the school years. Such information, if important, should be kept in a locked, confidential file.
- (3) In case of transfer, the records should be sent to the child's new school, even if it is in a different state or country.
- (4) The record should be available to the appropriate school personnel, particularly the home-room teacher, by permission of the principal, not the physician.
- (5) The principal should be the custodian of the pupil's medical record just as he is of the pupil's academic record.

LABORATORY. At present the majority of school health programs do not include routine laboratory tests. Experience in the past has shown that routine analysis of the urine usually uncovers little other than orthostatic albuminuria, but the cost of testing for albumin and sugar and determining the specific gravity is slight and can be educational as well as occasionally the first step to early discovery of an abnormal condition. On the other hand, routine hemoglobin determinations do turn up a few children with unsuspected mild to moderate chronic anemias either of the nutritional type or secondary to blood loss. With this in mind, routine hemoglobin determinations might be considered as part of a good school health program at least for high school girls if not for all pupils. A few positive serologies will be found by routine



testing but so few that the value of such a program lies more in the field of health education (Allison and Johnson, 1946). Chest x-rays and tuberculin testing should be in accordance with the tuberculosis control program of the community.

**IMMUNIZATION.** Though initial immunization procedures should be completed during the first 12 to 18 months of a child's life, there are always some children who reach school age without having been given any protection against diphtheria, whooping cough, tetanus, or smallpox. All of the children in an elementary school will need "booster" doses of immunizing agents once or twice during their six years of attendance.

The first contribution which the school health service can make toward improving the immunization program of the community is to help parents reach the point of wanting to have their children protected and then reminding them when "booster" doses are indicated. For children attending school, the school itself is the most convenient and least expensive place in which to have immunizations given whether as a full series or as "boosters." Clinic sessions can be arranged in which 60 to 100 children can be vaccinated or given injections of toxoid within an hour by one physician assisted by a nurse and a teacher or parent helper. Arrangements for such a clinic include scheduling, obtaining written requests from parents or guardians, and providing a supply of sterile needles and syringes sufficiently large to obviate waiting for resterilization. An ampule of adrenalin should be kept on hand for use in case of the very rare untoward reaction. Only immunizations should be done in such clinic sessions and the children should be informed in advance so that they may know what to expect, why this relatively unpleasant procedure is important to their health, and that there is no reason to fear a surprise "needle" when they go to the health room or suite at other times. The agent and the quantity administered and the date should be recorded on the pupil's medical record and a certificate showing the same data should be given or sent home to the parent.

**COMMUNICABLE DISEASE CONTROL.** Once again the classroom teacher is the key person in maintaining the health of his or her pupils by excluding children with communicable diseases. The observant teacher who pauses long enough at the beginning of the school day to note the general appearance of each pupil can detect signs of illness very quickly, for the teacher knows the child's usual appearance so well that the slightest deviation from normal is immediately apparent. There should be no need for the teacher to request the sanction of the nurse or physician in sending home children who appear to have a febrile or communicable illness. When the nurse is present in the school, it is most desirable, however, to have pupils check out with her so that she may be informed of the condition responsible for the exclusion, make certain that any needed medical or nursing care will be obtained, and list the pupil as one to inquire about at a later date.

In some areas of this country those attempting to eradicate tuberculosis are making full use of the school as the most convenient place to carry out mass tuberculin testing and chest x-rays. Other areas, which have a higher incidence of tuberculosis, are instead making use of the school for the giving of BCG (*Bacillus Calmette Guérin*) vaccine. Whatever the approach may be, the school health program should cooperate fully with the local tuberculosis program. In general it may be said that, with the rare exception of the area with a very high tuberculosis rate, control measures in the school age group will work more toward eradication of the

disease if tuberculin testing followed by chest films annually of positive reactors is carried out. The giving of BCG vaccine to negative reactors will, of course, eliminate the tuberculin test as an efficient and inexpensive means of continued case finding within the group.

Other aspects of communicable disease control include proper ventilation, hand-washing facilities and spacing of seats. Methods of diminishing the bacterial content of the classroom atmosphere are still in the experimental stage. (See page 157.) Self-exclusion of the teacher for communicable disease and annual chest films of all school personnel, including the bus driver, are of great importance. It must be remembered that the school bus and school cafeteria represent areas where spread of communicable diseases from one class group to another can be expected.

It is not unusual to encounter a public demand for closing of schools when epidemics arise in the community. Keeping the school open but providing enough additional time and personnel (if needed) to permit careful daily inspection of each pupil and prompt return to the home of suspects usually does far more to limit the epidemic than closing the school. In addition to disrupting the curriculum, closing the school will take some parents out of work, promote more widespread circulation of the pupils and leave health supervision and isolation of suspects up to the parents. Thus, many children either in the early (but highly infectious) stages of a communicable disease or throughout a mild attack will be permitted freedom of movement about the community instead of being kept at home, as a result of early recognition of the illness and exclusion by the school, at a time when the school-age child is immediately suspected if seen at large during school hours.

**Special Services, Including Health Education.** Special services for the promotion of health of the school child may include the pupil personnel activities, physical education programs, the school lunch program, and special classes such as those in health education, and human relations.

**PUPIL PERSONNEL ACTIVITIES.** The foregoing paragraphs have described the great and time consuming part played by the teacher in a school health program. Educators frequently ask the question: "But when will the teacher teach if all these things are expected of him or her?" It is true that proper attention to health increases the teacher's load and for this and many other reasons one must not expect the busy classroom teacher to take the initiative in planning activities intended to promote health. Any large school will benefit greatly from the services of a pupil personnel director—a person skilled in health and health education, who has had social service training and can act as a coordinator of the health program as well as a guidance counselor for the pupils. High schools often include a vocational guidance counselor on their staffs, but such people are seldom qualified to do more than this. A guidance counselor with the training of a psychiatric social worker can be of tremendous benefit to the total school health program and also to individual pupils by helping them to obtain medical care or by personally providing therapy for the less severe emotional disturbances.

**THE PHYSICAL EDUCATION PROGRAMS** (O'Keefe and Fahey, 1949). The physical education programs of today take cognizance of the importance of making the activities interesting to the pupils and of providing instruction in physical activities which may be useful to the child after graduating from school. These may include tennis, golf, swimming, and even fishing. The attempt to build strong bodies through



exercise is not forgotten, but the overemphasis on competitive sports has lessened. Some school systems depend upon the physical education teacher to teach health and act at the high school level as the person who takes the place of the elementary school home-room teacher in observing the health of the pupils and conferring with the nurse or physician about each child. In general, directors of physical education programs in large schools should not be coaches of major interscholastic sports.

**SCHOOL LUNCH PROGRAMS.** School lunch programs are designed to provide one thoroughly nutritious meal a day at a cost so low that it is available to all of the pupils. Federal subsidization through the School Lunch Act (Public Law 396, 1946) has made this possible in many schools. The school lunch must not be overlooked as an excellent educational medium through which children may learn some basic facts about nutrition and good table manners in addition to overcoming poor eating habits and food fads (Bryan, 1946).

**HEALTH AND SAFETY EDUCATION** (Wilson, 1948). Health and safety education is integrated throughout the curriculum with other subjects, often without the con-

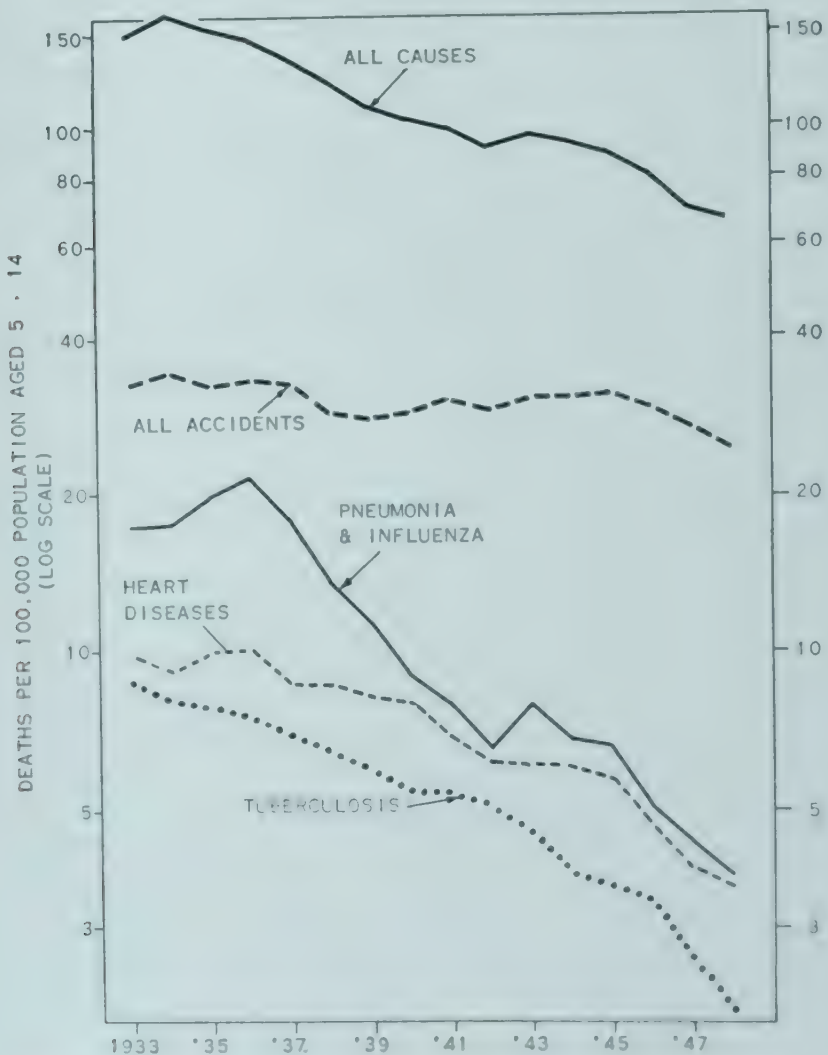


Fig. 17-1. Accidents, of which more than one third are motor vehicle, are the primary killer of school-age children. Comparable rates for 1952 as reported by The National Office of Vital Statistics were: all causes, 59; all accidents, 22.5; heart diseases, 3.95; pneumonia and influenza, 3.15; and tuberculosis, 0.95.

scious recognition of the teacher or pupils. Conscious effort must be made by health and education people to give more of this information to adults and particularly parents. The data presented in Figure 17-1 suggest the importance of safety education and some specific areas where more health education would be most desirable (National Safety Council).

The teacher properly educated in health will pass this knowledge along to the students without the need of special classes, but there is some value to providing a course in health and personal hygiene at the high school level. School nurses, school physicians, or health educators may be used to teach such a course, but the subject should not be treated as something that anyone with a bit of health knowledge can muddle through well enough to satisfy the requirements. Together with the home economics or homemaking courses, the health education course should provide the pupils with up-to-date information about their own anatomy, physiology, and psychology, so that they may understand the true meaning of physical, mental, and social well-being. The true facts about such things as menstruation, marriage, child-bearing, and child rearing should be offered in an effort to dispel some of the erroneous ideas which so many young couples and young parents seem to accumulate before marriage or parenthood. The content and teaching of a course in health and personal hygiene must be such that the pupils can readily relate the subject matter to themselves, their bodies and minds, and the function of each, or (the more impersonal material) to their community, family, or friends. Health education which deals with fine details such as annual increments of growth, calories per ounce of food, or the names of the bones in the human body is worse than useless, for it is seldom remembered and serves largely to make the course unpopular with the students.

**CLASSES IN HUMAN RELATIONS AND DEMOCRATIC LIVING.** Most people constantly find themselves at odds with their environment, sometimes in the form of minor irritations with community or family conditions, sometimes in the form of major disagreement with and inability to accept some of the basic dictates of the culture (Prescott, 1938). Usually, some change must be accomplished either in the person, the environment, or both, in order to avoid unbearable friction. Attempts to effect such changes are always in progress and should not be discouraged; but the mental and social well-being of most of us would be furthered greatly by our learning how better to get along more permissively and peacefully with people and conditions as we find them. Many schools are attempting to organize courses in democratic living, covering such subjects as human behavior, family relationships, beliefs, and values. The teaching of human relations in the classroom as developed by Bullis and O'Malley (1948) cannot be overlooked as a possible way to wide-scale promotion of mental and social well-being. Human relations classes are designed to help both pupils and teachers to learn how to get along better in their given environments. Case conferences held within the school, which include the teacher, nurse, principal, psychologist, physician and psychiatrist and provide direct help to teachers with some of their classroom problems, also contribute much to this effort.

**Summary.** The health of the child of school age will most certainly be affected by the school which the child attends. The ideal is of course to have this effect one which promotes the physical, mental, and social well-being of the child. Numerous ways in which this promotion of health may be approached have been described, but the extent to which any school or school system goes in furthering health will



depend upon the attitude of the parents, teachers, school administrators, and professional health people of the community at local, county, state, and national levels.

It is recommended that school health programs be a joint undertaking of the departments of health and education at all levels with federal and state directors of school health activities acting largely in an advisory capacity to create interest in, coordinate development of and give essential financial support to county and city programs.

That the school represents a convenient and logical place to provide certain health services goes without argument; the type and scope of the program will vary, however, depending upon local conditions.

The teacher's observation of the pupils' health should be accepted as an integral and most important part of any teacher's daily routine. Any deviations from good health thus noted must be referred for medical attention, and an "air-tight" follow-up system devised to keep those concerned appraised of whether or not the needed care has been obtained.

Vision testing can be and should be a part of every school's curriculum, and there is every reason to feel that pure-tone audiometry should be made available for all school children. Community resources must provide services for diagnosis and care of any vision and hearing defects which are uncovered.

Immunization procedures are easily carried out in schools with a minimum of wasted time and effort.

Consideration should be given to the opportunity the school affords for prevention and treatment of emotional disturbances.

Whenever funds and facilities permit, the school health program should include a public health nurse and physician trained in well-child care and working together in the school, part or full time depending upon the circumstances.

The teacher is recognized as the person upon whom school health programs must depend most heavily. If our school teachers are indeed the key people in promoting physical, mental, and social well-being in each and every school child it is obvious that their prestige, salary scale, working conditions, and knowledge of health must be greatly improved. Above all, in the selection of students, teacher training institutions must take more cognizance of the emotional maturity of the applicant. An emotionally mature teacher, if well trained, can carry on an acceptable school health program alone, even in a one-room rural school, by giving attention to the physical and emotional environment, by intelligent observation of the pupils (with referral through the parents to needed care), and by giving both the pupils and the parents an understanding of how to further "the healthy development of the child" and the child's "ability to live harmoniously in a changing total environment."

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# 18

## SERVICES FOR THE PHYSICALLY HANDICAPPED CHILD

EDWARD DAVENS, M.D.

Crippled children have been of concern to governmental and voluntary agencies for many years. Prior to the passage of the Federal Social Security Act in 1935, however, few states had developed a comprehensive program of services on a state-wide basis. During the initial 20 years of federal aid to the states for services to crippled children, much valuable experience has been gained in the development of a nation-wide program of medical, surgical, and other professional services for the physical restoration and social adjustment of children with various types of physical handicaps. Much also has been accomplished in the integration of these services with the already established programs of vocational rehabilitation. On the federal level, responsibility for administration of this part of the Act (Title V Section 2) is vested in the Children's Bureau of the Department of Health, Education, and Welfare. On the state level there is a varied pattern of administration, although in the majority (32 out of 53 "states" \*) the state health department is the responsible agency, and this appears to be the dominant trend. Other state agencies which administer this program include departments of education (3), welfare (9), state universities (4) and special commissions (5).

**Definition.** The definition of a crippled child varies somewhat from state to state. As originally interpreted, some gross disability of muscles, bones, or joints or interference with locomotion was implied. Thus, the principal causes of crippling listed on current state registers are infantile paralysis, cerebral palsy, clubfoot, osteomyelitis, congenital malformations, rickets, spinal curvatures, and tuberculosis of bones and joints. In more recent years, there has been a tendency to include the chronic physical diseases or disabilities which interfere with normal growth and development, education, or social adjustment. Many state programs now include various conditions requiring plastic surgery, severe dental problems requiring orthodontia, disabilities arising from impaired vision and hearing, speech disorders, rheumatic and congenital heart disease, epilepsy, and diabetes. This broadening definition is symbolized by increased use of the term "physically handicapped child" to replace "crippled child." The age limit established in all of the state programs is from birth to 21 years.

**Number of Physically Handicapped Children.** Information concerning the actual numbers of physically handicapped children of all types is incomplete. As

\* The term state as used here includes Alaska, the District of Columbia, Hawaii, Puerto Rico, and the Virgin Islands.

December 31, 1952 the various state registers contained the names of 756,000 physically handicapped children (U. S. Children's Bureau, 1953). Since this figure is largely composed of children with various types of orthopedic defects and congenital malformations and other conditions requiring plastic surgery, it represents only a fraction of the total number of physically handicapped children. Estimates of other important types of physical handicaps among children give a clue to the total magnitude of the problem. With respect to rheumatic heart disease, Paul (1943) concludes that the rate among school children varies between 0.3 to 4.0 per cent, and among college students from 0.6 to 1.0 per cent. Assuming 30 million children of school age and a rate of 1 per cent, there would be approximately 300,000 school children in the United States with rheumatic heart disease.

In the case of epilepsy, several studies (Hershey, 1945) indicate that one in 200 young men was rejected in the military drafts of World Wars I and II because of a history of epilepsy. At this rate there are in the neighborhood of 260,000 epileptics in the United States among the 52,000,000 individuals under 21 years of age.

Statistics on hearing loss are plentiful, but not very accurate because of variability factors such as method of testing, frequency of calibration of the instruments used, criteria for screening, acoustic conditions of testing room, presence of acute ear disease, and inherent subjective factors. For these reasons statistics on hearing loss are usually reported on the basis of children whose hearing appears sufficiently impaired to warrant further study. Most studies indicate that on this basis 5 per cent of school children have significant impairment of hearing (Lesser, 1950).

Speech disorder, either secondary to hearing impairment or associated with emotional disturbance, neuromuscular dysfunction, or congenital malformation, is an extremely common type of physical handicap which has profound implications for the educative process and for normal social adjustment. The prevalence of this type of disability has been variously estimated to be between 5 and 10 per cent of the school age population (Johnson and others, 1948).

Until recently, the only available estimate of incidence of cerebral palsy was the formula of Phelps (Perlstein, 1947) based on "repeated samplings done in New Jersey, Maryland, and other areas." According to this estimate, seven infants with cerebral palsy are born every year in each 100,000 population, of whom one dies before reaching six years of age. The prevalence of cerebral palsy in persons of all ages according to Dr. Phelps' estimate would be 400 per 100,000 population. This includes cases of all grades of severity. In a recent survey (N. Y. State Legislative Committee, 1949) in Schenectady County, New York, the prevalence of cerebral palsy in a sample of 22,528 persons was found to be in essential agreement with Phelps' estimate.

## VOLUNTARY ORGANIZATIONS

For many years various private agencies and fraternal societies have done pioneer work in developing programs to help the physically handicapped child. A characteristic of these efforts has been the categorical approach in which one or more organizations would interest themselves in a single type of physical handicap. However, the International Society for Crippled Children, founded in 1921, gave leadership to public efforts in behalf of all physically handicapped children and



sponsored legislation in their behalf. As successor to the international organization in this country, the National Society for Crippled Children and Adults was organized in 1939 and with its 2,000 affiliated local and state societies provides an over-all program of a variety of activities in the fields of health, welfare, education, recreation, rehabilitation, and employment for all types of handicapped persons.

The custom, starting in 1934, of nation-wide celebrations of the birthday of Franklin D. Roosevelt to raise money to control infantile paralysis, resulted in 1938 in the organization of the National Foundation for Infantile Paralysis "for the express purpose of leading, directing, and unifying the fight on every phase of infantile paralysis." This Foundation has stimulated the organization of local chapters covering nearly all of the 3,050 counties. One half of the funds raised each year is retained locally to assist in providing medical, surgical, nursing, physical therapy, and hospital care, as well as provision of orthopedic appliances and certain special equipment for hospitals. The chapters also contribute to the training of doctors, nurses, and physical therapists in the care of poliomyelitis patients. National funds are used to finance many important research projects related to poliomyelitis and to provide an "epidemic fund" for use in areas of greatest need. There is close cooperation in most states between the program of the Foundation and that of the official state agency responsible for services to crippled children.

In recent years, there has been a rapid rise of interest in the problems of the child with rheumatic fever, rheumatic heart disease, and, quite recently, congenital heart disease. The American Council on Rheumatic Fever, which functions as a part of the American Heart Association, is directing development of training programs, scientific research, and public education, working through affiliated state societies.

The National Society for the Prevention of Blindness conducts a vigorous educational program in behalf of children and adults with various types of visual handicaps, initiates special studies, and stimulates the development of adequate vision-sight conservation programs locally, especially in schools.

In 1949, the American Epilepsy League and the National Association to Control Epilepsy merged to form the National Epilepsy League which is now actively carrying out an educational program and promoting interest in establishing more adequate public health programs for this prevalent, misunderstood, and neglected disability.

There are a number of groups which focus their activities on speech and hearing disorders. The American Hearing Society (formerly the League for Hard of Hearing) which has 111 chapters chiefly in the larger cities, carries out educational activities and assists with developing of public health programs to prevent deafness, to conserve hearing, and to rehabilitate individuals with impaired hearing. The Volta Bureau is a pioneer agency which conducts a national educational program of speech and hearing disorders with emphasis on teaching the "oral method" of communication, and in general acts as a national clearing house for all information concerning speech or hearing disorders. Important professional organizations concerned with developing high standards of professional training for nonmedical specialists dealing with speech and hearing problems are the American Speech and Hearing Association, the American Speech Association, and the Audiology Association. The American Academy of Ophthalmology and Otolaryngology has several standing committees on the conservation of hearing and related problems.

Responding to a tremendous upsurge of interest in cerebral palsy, the Nation

Society for Crippled Children and Adults organized in 1946 a National Cerebral Palsy Division. Other national groups interested in this condition include the United Cerebral Palsy Association and the National Association for Cerebral Palsy.

In addition, there are numerous fraternal societies, clubs, and other groups such as Shriners, Rotary, Lions, Elks, Kiwanis, and American Legion which are interested in crippling diseases, usually in a specific type of handicap.

This partial list of private agencies provides unmistakable evidence of the intense and widening popular interest in the field of children with long-term illness or disability. On the other hand, it illustrates the increasing trend toward a categorical or segmental approach to isolated public health problems which should be integrated with the total community health program. Unfortunately, preoccupation with the individual category often has resulted in forgetting that one is dealing with the health of the "whole child," which means his physical, mental, and social well-being, not merely the absence of disease or infirmity. That the child was a physical handicap has all the health problems of any growing and developing child in addition to the special problems which may be associated with his particular disability is a principle far too frequently overlooked. Another disadvantage of the too-exclusive categorical approach arises from the frequency with which physical handicaps are multiple. For example, approximately 30 per cent of children with cerebral palsy also have convulsive seizures, and a large additional group have speech disorders. The child with a cleft palate is not just a case for the plastic surgeon, but needs the attention of the pediatrician, speech therapist, and prosthodontist or orthodontist as well. The child with a "reading disability" seldom has problems confined to the visual apparatus alone, but not infrequently has hearing impairment, emotional disturbances, and other problems. The tendency to duplication of service, lack of economy and poorly balanced emphasis inherent in the one-interest agency approach has been discussed in detail by Gunn and Platt (1945). That there are also important advantages to be gained from the one-interest agency is undeniable. A discussion of both sides of the question can be found in the study of voluntary agencies (Gunn and Platt, 1945) which was sponsored by the National Health Council.

## STATE PROGRAMS

Although there is a basic similarity among the various state plans for crippled children's services, each is adapted to the particular needs of the state and is supervised by the official state agency. A recent review (Davens, 1955) summarizes the progress states have made in developing services for crippled children during the 20 years since the passage of the Social Security Act in 1935.

State programs have worked out methods of cooperation among themselves and other allied agencies. An example is the working arrangement with the National Foundation for Infantile Paralysis which operates a medical care program for a specific crippling disease. Of exceptional importance is close collaboration with related public programs such as special education and vocational rehabilitation services.

In a few states eligibility for care must be determined by court order in the county court in which the child resides. In the remaining states the official state agency has the sole responsibility for determining eligibility for care. Laws and state policies vary concerning residence requirements. The Children's Bureau Advisory



Committee on Crippled Children on several occasions has recommended discontinuance of any requirements concerning length of residence as a prerequisite to eligibility for care. This would seem to be a desirable course since migration across state lines has greatly increased and since the program receives financial support from federal funds. There is now a wide acceptance of the principle that the physical restoration of the child with long-term handicapping illness is largely a public responsibility and provision of care should not be limited to the indigent. Consequently, financial eligibility policies in this particular specialized type of medical care program are less controversial. It is worth while to examine the reason for this.

In most crippling conditions the therapeutic services needed are not short term, infrequent, and inexpensive; rather they are likely to be long in duration, frequent, and extremely expensive. Many families are unable to meet the full cost, and financial assistance in whole or in part is needed. Poverty is a relatively unalterable condition, and its cure is beyond our scope, for the present at least. Methods of mitigating its impact on society consist in supplying a basic minimum of food, clothing, and shelter, using rigid formulae of income as a guide. In the case of a physical handicap, on the other hand, medical science has provided the tools to remove or minimize the disability transforming the individual from the potential status of a public dependent to a useful, happy, and employed citizen. Rather than schedules of income level, the criterion here should be based on medical need, using the skills of the medical social worker either by interview or consultation to determine on an individual basis what financial contribution the family can be expected to make.

An important responsibility of a state agency developing a program for all physically handicapped children is the achievement of a reasonable balance of emphasis between the different categories of handicap and the establishment of priorities for expenditures based on sound public health criteria. The fact that present funds available for this purpose are limited gives further emphasis to this consideration. There are a number of useful criteria in determining the quantity of effort and dollars which should be allocated to a particular handicap:

- (a) The number of children affected.
- (b) The amenability of the handicap to medical therapy and preventive measures.
- (c) The cost per child to secure maximum benefit.
- (d) The likelihood of the child's becoming, if untreated, dependent, unemployable, and a permanent public responsibility at far greater cost.
- (e) The unfavorable effect of the handicap on the emotional status of the child and his family.
- (f) The extent of interference with satisfactory progress in school.
- (g) The progressiveness of the condition.
- (h) The availability of special personnel and facilities for treatment.

When faced with the problem of budgeting a limited amount of funds for a complete program for all physically handicapped children, points (a), (b), and (c) above are of greatest importance. It would seem that the wisest policy from the public health standpoint would be to plan in such a way that the available resources are directed toward securing the maximum benefit for the greatest number of children at the least cost per patient.

## ESSENTIAL SERVICES

Regardless of the nature of the particular handicap, the basic approach in a program providing complete care is essentially the same. Whether one is developing services for children with orthopedic defects, cleft palate, hearing impairment, speech disorder, rheumatic heart disease, or epilepsy, the essential components to insure the advantages of continuous and interrelated care of high quality are the same. The objectives of medical care must include promotion of positive health; prevention of disease, disability, and attendant economic insecurity; cure or mitigation of disease; and rehabilitation of the patient. The quality of medical care is of exceptional importance in dealing with physical handicaps of children because to achieve the best results that modern medical science has to offer, the teamwork of various types of medical and other specialists is required, and the stakes one is playing for are the entire future development, educational achievement, and vocational adjustment of the individual.

Continuity of care is of special importance in the planning of services for care of long-term illness in growing and developing children. Such care involves attendance by the same physician, dentist, nursing team, social worker, and so forth throughout the course of the child's illness or disability. There may be need, of course, for various types of medical consultants and for referral to different qualified personnel such as clinical psychologists, clinical audiologists, speech therapists, and others. Nevertheless, the principle of continuity of care should ensure that the child remain under coordinated management throughout all phases of treatment. Continuous care must not only be well integrated, but also complete in its various aspects. High quality of service is difficult to achieve unless home, clinic, and hospital care are all developed with smoothly functioning interrelationship. The full range of health service—from prevention through vocational rehabilitation—should be developed for each type of handicap and should be made readily available to the child and his family in such a way that the total needs of the particular child are the chief consideration.

Keeping this principle of continuity of care in mind, it is convenient to consider separately the essential services in a program for physically handicapped children; these may be listed as (a) prevention, (b) case finding, (c) medical and other professional diagnosis and treatment, (d) hospital and convalescent care, (e) special education, vocational rehabilitation and other after-care.

**Prevention of Physical Handicaps.** As in any other public health program, planning for the total needs of physically handicapped children should incorporate all available preventive measures. The most effective accomplishment of this objective follows when there is smooth integration of services for physically handicapped children with the health program for all mothers and children. It has already been pointed out that handicapped children have all the health problems of any growing child in addition to the special problem imposed by their disability. Even more important, however, is the fact that diligent and unremitting application of preventive health measures to all expectant mothers and children will be reflected in substantial reduction both in the quantity and severity of the crippling conditions to be found on the crippled children's registers.

Easily available and improved obstetrical care should be a cornerstone of efforts



to prevent physical handicaps. A wide variety of problems is susceptible to this approach. Congenital syphilis is also called "negligent" syphilis (Huse and Aufranc, 1950) because negligence in maternity care is the only reason for its continued existence at the rate of 14,000 reported cases each year; all this, in spite of the effectiveness and availability of penicillin.

Erythroblastosis fetalis, a cause of cerebral palsy, can be controlled in some measure by more adequate antenatal care with attention to recognition of Rh incompatibility. The association of maternal rubella with abnormalities of the infant's hearing, vision, and cardiac function are now well established. Improved obstetrics will also diminish the incidence of various types of birth injuries. According to Dunham (1948) premature infants are peculiarly susceptible to birth injury because of immaturity of the various body structures and tissues. Since birth injury is an important causative factor of physical handicaps, the prevention of prematurity is pertinent and already has been discussed above.

Associated with improved measures for control, there has been a decline in the numbers of cases of tuberculosis of the bones and joints on state crippled children's registers. In the light of our present knowledge about this disease, there is no reason why crippling from tuberculosis should not be brought under complete control.

This is likewise true of rickets. The fact that this latter condition is still a cause of crippling at all is a severe indictment of the preventive program.

Both among infants and preschool children, accidental burns rank second as a cause of death and disability (Wolff, 1948). Motor vehicle and various types of home accidents are extremely important in the preschool and school-age years, constituting the most important cause of death from any cause in the latter group and also providing a major source of long-term physical handicap. Every state crippled children's register contains the names of children with paraplegia or other serious handicap due to accidental gunshot wounds. In the southern states accidental lye burns resulting in esophageal stricture are common. There is room for significant improvement in reducing physical handicaps through better means of accident prevention.

Analysis of causes of blindness gives dramatic evidence of how much disability is preventable. In a study of causes of blindness among 20,591 recipients of aid to the blind (Hurlin and others, 1947) it was found that 1,551 cases were due to trachoma; 899 cases resulted from trauma associated with accidents; 1,589 were charged to syphilis; 428 to ophthalmia neonatorum; 101 resulted from poisoning; 36 from smallpox; 132 from meningitis; and 111 from measles. Preventive measures for retrolental fibroplasia, recently an alarming contributor to blindness among prematurely born infants, have been established. Elimination of prolonged and excessive oxygen among the smaller newborn infants is effective (Gordon, 1954).

The general principle of early diagnosis and adequate treatment has wide application as a potent preventive measure. In this connection, recent studies (Houser, 1952) demonstrate that recurrences of rheumatic fever are prevented or greatly reduced when the child is brought under adequate medical supervision during and after the initial attack of the disease. In this way, the crippling effects of rheumatic heart disease are either completely avoided or greatly reduced.

There is increasing evidence (Proctor and others, 1948) to support the view that early recognition of impaired hearing and the prompt institution of otological

therapy including irradiation of the lymphoid tissue of the nasopharynx can prevent progressive loss of hearing due to chronic disease of the middle ear. In the field of speech disorders, there have been some encouraging demonstrations in nursery schools of the effectiveness of early and intensive speech therapy in minimizing speech difficulties associated with hearing impairment. As our knowledge of the nature of rhythmic speech disorders such as stuttering increases, preventive measures (Johnson and others, 1948) will be more extensively applied.

Early diagnosis and prompt, intensive treatment with antibiotics has continued to greatly reduce the disability from osteomyelitis. The new vaccine recently developed for poliomyelitis promises to eventually control the paralytic effect of this disease (Francis, 1955).

The principle of early diagnosis, prompt treatment, and application of the full range of aftercare services, particularly physical therapy, has greatly minimized the paralytic effects of poliomyelitis.

**Case Finding.** The goal should be to achieve continuing rather than sporadic case-finding. The best method of accomplishing this is the stimulation of interest in periodic health supervision of young children on the part of physicians, nurses, teachers, social workers, and parents. A new guide (Child Health Committee, 1955) provides an excellent summary of current concepts and procedures for such health supervision.

Physician-reporting to the health department has been unsatisfactory (e.g., in the case of rheumatic fever) in some potentially handicapping diseases and satisfactory (poliomyelitis) in others.

In general, special surveys are an expensive and disappointing method of case finding. Experience in such programs as conservation of hearing and rheumatic fever and heart disease indicate that provision of easily available specialized clinical diagnostic facilities is a far more effective method of learning about the extent and nature of the problem. The accurate diagnosis by specialists also permits classification of the cases according to severity which is essential information in planning treatment services.

In some cases—for example, congenital malformations—birth certificates have been successfully used as a case-finding technic.

School censuses are another source, but have the drawback usually of discovering only gross handicaps at a stage where the advantages of early recognition and treatment are lost. However, newer methods of case finding in school programs by various screening technics are showing excellent results in ferreting out the more subtle types of physical handicaps such as visual defects, mild hearing loss, speech disorders, and rheumatic fever. For a discussion of these technics, which include daily teacher observation of school children, teacher-nurse conferences, vision testing, audiometer testing, and mass photo-fluoro-roentgenographic surveys, see the section on school health services, Chapter 17.

Close working relationships with welfare departments in the matter of adoption and foster home placement provide another source for locating children in need of physical rehabilitation. Liaison with hospital newborn nurseries and with the various other hospital care programs (e.g., in welfare department) are other sources which require further exploration.



**Diagnosis and Treatment.** Skilled diagnostic services are furnished in state clinics staffed by qualified surgeons, pediatricians, and other medical and nonmedical specialists. These clinics are conducted either in permanent centers or periodically in various rural communities so as to be accessible to any part of the state. Most widely developed are clinics for orthopedic problems and for cases requiring plastic surgery. In the interest of continuity of care, every effort should be made to insure that the same physician who makes the diagnosis, treats the child in the hospital and also participates in the after-care. As in other health programs, the interprofessional teamwork between physicians, public health nurses, medical social workers, and others is being used with conspicuous success in this phase of the program. Increased teamwork between various specialists actually involved in the diagnosis and treatment is another current trend. An example is initial planning conference between the plastic surgeon, the pediatrician, the speech therapist, and the prothodontist or orthodontist in working out a regimen of therapy for cleft palate cases (Baker, 1949).

In the case of diagnosis and treatment of children with hearing impairment and associated speech disorder, the cooperative endeavor on the part of the otolaryngologist, the clinical audiologist, and the speech therapist in a closely-knit clinical program, permits the consideration of the fundamentals of hearing disability as a "communicative disorder" and fosters "the psycho-social adjustment of the hard-of-hearing person" (Pauls and Hardy, 1948).

In most states, the clinical facilities for orthopedic handicaps, including poliomyelitis and defects requiring plastic surgery, are better established and have statewide coverage. However, there has been rapid advance in the development of state programs to provide services for other types of physical disability. Most of these newer programs are on a demonstration basis, however, and frequently only a part of the state, often a single county, is served.

Children with cerebral palsy are another group for which clinical services are being rapidly developed under both public and private auspices. Cost of treatment and training is extremely high. In 1947, the California State Legislature made a substantial appropriation to initiate a state program for the care and training of these children and in 1949, following a special study (N. Y. State Joint Legislative Committee, 1949), the New York State Legislature did likewise. In addition, a few other states have taken initial steps to develop well-rounded programs for these children although in most instances the geographic area covered is limited.

It is difficult to make any general statement regarding speech and hearing programs in the States. 42 or more States make at least some provision for services to children with impaired speech or hearing. Sixteen States have programs for children with hearing impairment which are more complete than the others. In some cases services are limited in coverage, either geographically or in completeness of program offered. A few States have demonstrations in speech or hearing, most of which have been training rather than service projects.

In 1955, at least nine States had a program for children with convulsive seizures, and eleven or twelve others were serving a few children with epilepsy.

The Children's Bureau reports that official state agencies operating programs of services for crippled children provided diagnosis and treatment in clinics to 221,000 children in the calendar year 1954. The total number of clinic visits was 468,000.

**Hospital and Convalescent Care.** During the calendar year 1954, official state crippled children's agencies alone provided hospital care to 43,000 children, purchasing a total of 1,207,000 days of care (average of 27.8 days per child). These same agencies provided convalescent home care to 4,000 children for a total of 413,000 days of care (average 99.9 days per child). In addition, of course, very large quantities of hospital and convalescent care for physically handicapped children were purchased by numerous other public agencies and voluntary agencies such as the National Foundation for Infantile Paralysis, Community Chest agencies, religious and fraternal groups, and others. All this implies a considerable amount of responsibility on the part of the agency providing the care regardless of whether it is public or private. This responsibility involves such considerations as selection of hospitals on the basis of their ability to provide the type and quality of care needed, and in long-term cases whether they have educational and occupational therapy facilities and whether there are adequate social services to maintain contact with the family and arrange for after-care in the home if needed.

With respect to the first of these responsibilities—the selection of hospitals on the basis of their ability to provide the type and quality of care needed—it is well to view the whole problem of long-term illness rather than the segment of the problem posed by special needs of handicapped children. Undoubtedly, long-term illness has become one of the outstanding unsolved problems of our day, even though the use of this term rather than “chronic illness” reflects a more hopeful attitude of mind (Bluestone, 1947). The very large numbers of persons, children and adults, requiring long-term care presents a serious problem to hospital and convalescent sanatoria administrators. In a joint statement (American Hospital Association, 1947) the American Hospital Association, American Public Welfare Association, American Public Health Association, and American Medical Association recently pointed out that “the general hospital as at present constituted is often unsuited to the care of long-term patients, since it is geared primarily to the therapeutic and general requirements of the acutely ill. It may lack adequate departments for physical therapy, and rehabilitation, as well as sun porches, recreational facilities, educational facilities for children and an understanding of the social and psychologic needs of the chronically ill.” Moreover, care provided in the acute general hospital for long-term care is much more costly in spite of the fact that it is often unsuited to the patient's needs. The report finds encouragement in the construction of new facilities for long-term care by the Hospital Survey and Construction Act, but deplores the continued tendency in some areas to build such hospitals in remote areas with no relation to teaching medical centers and the general hospital. It goes on to point out that “hospital facilities for long-term illness should be built in the very closest relation to teaching centers and general hospitals.” Most state agencies administering programs of care for physically handicapped children have established standards for hospitals and convalescent homes from whom they purchase care. In a rapidly increasing number of states there are hospital licensing laws which are frequently administered by the state health department, and there is an encouraging trend toward provision of hospital consultation service in the fields of pediatrics, obstetrics, nursing, and nutrition in association with the hospital inspections which are a part of the licensing program. Standards for convalescent care of children (Subcommittee, N. Y. Academy of Medicine, 1948) have been carefully worked



out. A recent study (U. S. Department of Labor, 1949) of a single convalescent home restates current thinking on the general principles and meaning of convalescent care and contains an excellent bibliography.

A health agency purchasing hospital care for physically handicapped children, particularly if it be a state agency, frequently finds it is desirable to enter into a written agreement with the hospital. Items which are frequently covered by such agreements include the responsibility of the agency for payment for services authorized and rendered, for submitting to the hospital information about the patient, and for assuring proper follow-up care; the use of an inclusive per diem rate for all services and reference to the method of calculating this rate; the method of authorizing services; a provision for the hospital to accept payment only from the agency for services authorized by the agency; and reference to the standards of hospital care required by the agency purchasing the care.

With respect to authorization of care, it is customary for the agency purchasing the care to furnish the hospital selected with formal authorization for the care, stating the period to be covered and any other conditions which may have been agreed upon.

When federal funds are used to purchase care for handicapped children (also used by vocational rehabilitation programs) payment is made at an inclusive per diem rate to cover all the services provided to a patient by a hospital. This rate is calculated according to a formula \* which insures that the rate of payment is not in excess of the average cost per patient day. Maximum or ceiling rates are frequently adopted by state agencies, however.

Finally, any agency purchasing hospital care for physically handicapped children should accept the responsibility of cooperating with any other agency, public or private, in order to develop procedures and rates of payment which are as uniform and reasonable as possible. In the case of an agency operating a crippled children's program, there is special need for cooperation with maternal and child health services, vocational rehabilitation services, National Foundation for Infantile Paralysis, and similar agencies in matters pertaining to purchase of hospital care.

**Special Education, Vocational Rehabilitation and Other After-care.** The ultimate aim in physical restoration is the successful educational, social, and vocational functioning of the individual. Any program of services for the physically handicapped child which does not take into account provision for adequate special education, vocational rehabilitation and other after-care is seriously remiss. Furthermore, it must be recognized that the resultant benefit a child receives from after-care depends upon the adequacy of the resources in his home community. It is feasible to solve certain medical or surgical problems in diagnosis or treatment by bringing specialists to clinics in rural areas or even by transporting children beyond state borders, as is done for example when certain children are transported by air from Alaska to Seattle for operation. It is not possible, however, to provide the day-by-day public health nursing, medical social and physical therapy services in the home or the long-continued special education and vocational guidance which are needed unless these facilities are developed within the child's own home town or county.

As local public health departments develop there is a growing tendency to pro-

\* Children's Bureau and Office of Vocational Rehabilitation, Department of Health, Education, and Welfare, and Veterans Administration, Joint Hospital Form 1, September 1954.

vide public health nursing, medical social, physical therapy, occupational therapy, and other needed after-care services as a part of an integrated public health program. State nursing, medical social, and physical therapy consultants are being used to assist the local health officer in improving the education and productiveness of their respective professional local staff members. These consultants assist local nurses, social workers, physical therapists and others in carrying out their duties relating to the follow-up of children with physical handicaps who have had initial medical diagnosis and treatment, but who are in need of various types of continuing care such as interpretation of handicap to family, home nursing, physical therapy, special diet, appointments for return visits to clinic or hospital, home occupational therapy, routine well-child supervision, and a host of other items which form the pattern of really complete after-care.

The essential contribution of special education to the rehabilitation of the physically handicapped child is now widely accepted. Even after all available medical, surgical and other professional skills have been brought to bear on the cure or mitigation of the physical handicap, there will continue to be children who deviate sufficiently from the "normal" to require special skills on the part of the teachers or other school personnel. The current terminology used to designate this group is "exceptional children." This term refers "to those who deviate from what is supposed to be average in physical, mental, emotional, or social characteristics to such an extent that they require special educational services in order to develop to their maximum capacity." These special educational services may include a radical modification of the curriculum, special methods of instruction, special equipment, or an adjusted school schedule.

World War II, by demonstrating that the handicapped are excellent workers, gave tremendous impetus to the special education movement and, by 1948, 41 states had enacted laws authorizing or requiring local school districts to make special provisions for one or more types of exceptional children. Thirty-four of these states have provided funds to help the local districts finance the program. Statistics gathered for the year 1947-48 indicate that approximately 365,000 exceptional children were enrolled in special schools and classes or home or hospital instruction provided by local school districts (National Society for the Study of Education, 1950). This figure includes children with mental, emotional, and social deviations as well as physical handicaps.

For a detailed discussion of the principles of special education, the essentials of a well-rounded program, and the needed educational provisions for specific types of handicaps, the reader is referred to the 49th Yearbook of the National Society for the Study of Education.

Vocational rehabilitation, as provided today by the states assisted by the Federal Government through grants-in-aid, is a service to preserve, restore, or develop the ability of disabled persons to engage in gainful employment. In relation to services for physically handicapped children, it is the crucial end stage where the child with handicap is assisted in preparing for and finding suitable employment. United States Public Law 165 enacted in 1954 liberalized and extended the Vocational Rehabilitation Acts of 1920 and 1943 which extended grants of federal funds to states to develop programs for vocational rehabilitation. The purpose is to increase the number of persons rehabilitated from 60,000 to 200,000 per year by 1959.



(Whitten, 1954). This act is administered by the Office of Vocational Rehabilitation in the Department of Health, Education, and Welfare. Similar to the crippled children's programs, state plans describing policies and procedures and administrative organization are required. In 1953 state rehabilitation agencies reported 61,308 persons were vocationally rehabilitated (U. S. Office of Vocational Rehabilitation, 1954). During this same year, total expenditures were approximately \$22,947,851 from federal funds and about \$11,635,557 from state funds. The need for close cooperation between vocational rehabilitation and crippled children's services has already been cited. The Children's Bureau and the Federal Office of Vocational Rehabilitation have agreed upon certain policies designed to avoid duplication of services, and most state agencies administering these two programs have adopted similar agreements which, among other things, provide for referral of crippled children of employable age to the state vocational rehabilitation services.

In summary, the essential components of an adequate total program of services for physically handicapped children are as follows:

Provision should be made for the inclusion of all types of physical handicaps which interfere with normal growth and development, or successful educational, social, and vocational functioning of the individual.

By integration with the over-all public health program, persistent emphasis should be placed on the prevention of physical handicaps rather than indulging solely in a salvage campaign to mitigate disabilities which need never have occurred.

The case-finding effort should be organized on a continuing rather than a sporadic basis by stimulation of interest on the part of physicians, nurses, teachers, social workers, and parent groups. The goal should be toward early diagnosis and treatment.

Medical and hospital care should be readily available to all children on the basis of medical need and there should be no limitations because of residence, race, creed, or color. Methods of removing the financial barrier between the child and the needed care should be worked out on an individualized basis with the assistance of the medical social worker. Various other professional diagnostic and therapeutic skills should be available and the trend toward interprofessional teamwork encouraged. High standards of quality of care should be fostered at all times.

Modern convalescent sanatoria should be provided for the various types of illness or disability in stages not requiring general or special hospital care. For those children needing prolonged convalescence at home, an organized program of after-care should be available to assist and supplement the care afforded by the family physician. Among the services needed are those of the public health nurse, the medical social worker, the nutritionist, the physical therapist, the occupational therapist, and the home teacher.

Teachers or other personnel with special skills should be available in the schools for the education of those children who, after the application of all medical and surgical skills, continue to deviate significantly from the "normal."

Vocational rehabilitation services should be fully available in any part of a state to assist the child (or adult) with a residual handicap to develop or restore his ability to find suitable employment. Finally, a public educational program should be planned to remove, insofar as possible, the unreasonable and unfounded prejudices which interfere with the employment of handicapped persons.

For the effective accomplishment of these objectives, nothing short of united effort of an informed community will suffice.

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# 19

## SENESCENCE, CHRONIC DISEASE AND DISABILITY IN ADULTS

LESTER BRESLOW, M.D.

**Relative Importance.** During the past half century, advances in the standard of living, including preventive medicine, have vastly altered the pattern of morbidity and mortality in the United States. In 1900, the leading causes of death were tuberculosis, pneumonia, and enteritis. Today these diseases are of secondary importance as causes of death; their former places are now occupied by cardiovascular diseases and cancer.

Table 19-1 indicates the remarkable change which has occurred in the principal causes of death. The decrease in the communicable diseases and increase in importance of the chronic diseases represents both a tribute and a challenge to preventive medicine. Improvements in diagnosis and treatment, sanitation, nutrition, housing, and conditions of labor, as well as the more specific preventive measures such as immunization, have played important roles in the conquest of the communicable diseases. Most recently chemotherapy has hastened their decrease. These measures have already virtually eliminated many previously important diseases, and opened the path to eradication of others.

The relative and absolute increase of the chronic diseases has been due in large part to the survival of more persons into the later decades of life when these diseases are more prevalent. During the first half of the twentieth century, the average expectancy of life at birth (for white males) increased from 48 to 67 years.

**Aging of the Population.** Figure 19-1 indicates the steadily increasing proportion of persons in the older age groups in the United States. In just 100 years—from 1860 to 1960—the proportion of persons under 20 years of age will have dropped from one half to less than one third of the total population. In this same period the proportion in the age group 45 to 64 will have doubled, and in the age group 65 years and over the proportion will have tripled.

The changing age composition of the population (i.e., the increasing proportions of persons in the older age groups) is changing the orientation of preventive medicine. Whereas previous efforts have been directed largely to the control of the communicable diseases of early life, efforts are now being focused to an increasing extent on the diseases common in middle and later life—the chronic diseases.

**Age Relationship.** Aging and chronic disease are closely related by separate phenomena. Increasing interest is being shown in the problems of an aging population not only by physicians but also by other professional groups. At this point it is appropriate to differentiate several concepts used in this field, i.e., senescence (the

Table 19-1. Death rates for leading causes of death, Death Registration States, United States,<sup>1</sup> 1900 and 1950

Rank Order	1900 <sup>a</sup> Cause of Death	Rate per 100,000	Rank Order	1950 <sup>b</sup> Cause of Death	Rate per 100,000
	All causes (343,217 deaths)	1719.1		All causes (1,452,454 deaths)	963.8
1	Pneumonia (all forms) and influenza	202.2	1	Diseases of the heart	355.5
2	Tuberculosis (all forms)	194.4	2	Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues	139.8
3	Diarrhea, enteritis, and ulceration of the intestines	142.7	3	Vascular lesions affecting central nervous system	104.0
4	Diseases of the heart	137.4	4	All accidents	60.6
5	Senility, ill-defined, and unknown	117.5	5	Certain diseases of early infancy	40.5
6	Intracranial lesions of vascular origin	106.9	6	Influenza and pneumonia except pneumonia of newborn	31.3
7	Nephritis	88.6	7	Tuberculosis (all forms)	22.5
8	All accidents	72.3	8	General arteriosclerosis	20.4
9	Cancer and other malignant tumors	64.0	9	Chronic and unspecified nephritis and other renal sclerosis	16.4
10	Diphtheria	40.3	10	Diabetes mellitus	16.2

<sup>1</sup> The Death Registration Area did not include all states until 1933. Therefore, data for 1900 do not represent mortality for total United States.

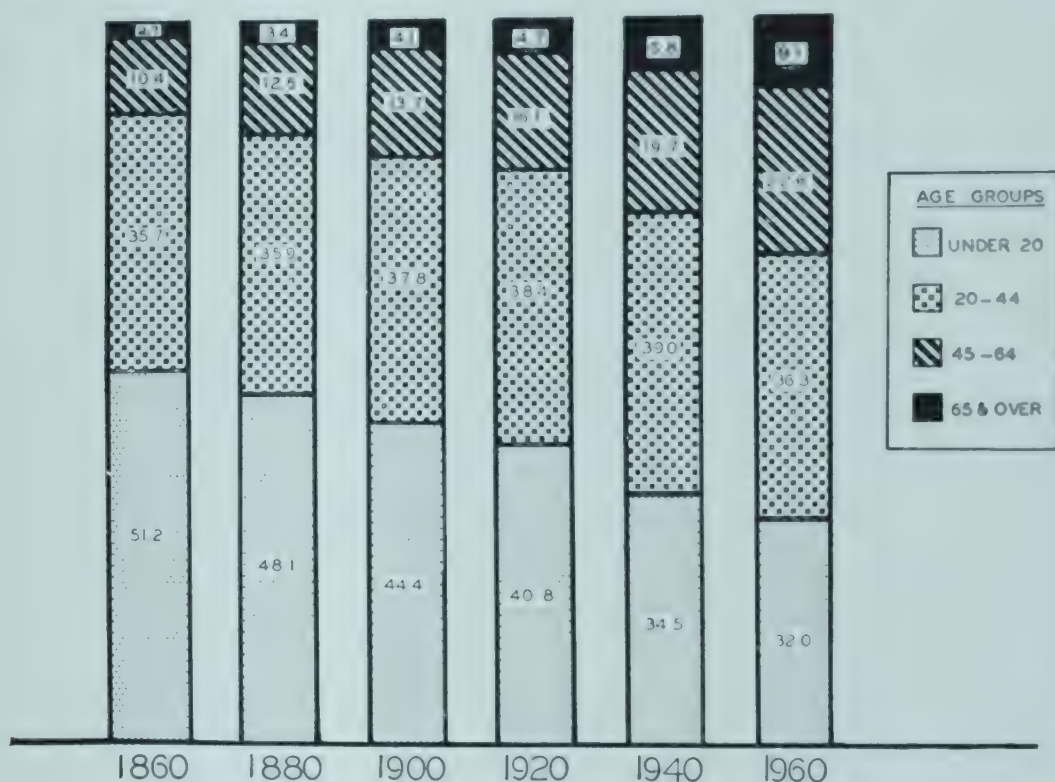
<sup>a</sup> First Revision, International Statistical Classification of Diseases, Injuries and Causes of Death, 1900.

<sup>b</sup> Sixth Revision, International Statistical Classification of Diseases, Injuries and Causes of Death, 1948.

Source: National Office of Vital Statistics, *Vital Statistics of the United States, 1950*, Vol. I, Table 8:43, p. 209.



process of growing old); gerontology (the science of the physical and psychological changes which are incident to old age); and geriatrics (the treatment of problems peculiar to old age). Senescence is an inevitable, normal biological phenomenon. In the case of some conditions we are now quite limited in ability to differentiate



From Dublin, Lotka and Spiegelman, *Length of Life*. Courtesy of the Ronald Press Co.

Fig. 19-1. Per cent distribution of total population by age; United States, 1860 to 1960.

senescence in its pure sense, from pathological changes occurring in old age as a result of environmental factors in earlier life. However, the leading chronic diseases represent well recognized pathologic processes and should not be confused with senescence.

Although more prevalent in the older age groups, these diseases occur at any age. The National Health Survey (1935-1936) revealed that fully one half of the chronically ill persons in the United States are under the age of 45 years. More than three fourths are in the productive years from 15 to 64. Hence, preventive and other measures for the control of chronic disease should be directed toward the whole age span of the population.

**Associated Factors.** Many persons view the chronic diseases—frequently referred to as the “degenerative” diseases—as inevitable concomitants of the aging process. This way of thinking, which has no scientific basis, leads to defeatism in control and rehabilitation efforts. It attempts to conceal our ignorance of these diseases and tends to discourage inquiry into their etiology. Within the medical and allied professions there is increasing dissatisfaction with the concept of the inevitability of many of these diseases—the concept that little if anything can be done to prevent, arrest or cure them. This shift in thinking is not based on the mere desire to substitute optimism for pessimism. Rather it is based on mounting evidence that

environmental factors rather than a mysterious "aging process" play the decisive role in the etiology of at least some of the diseases misnamed "degenerative." There is considerable evidence supporting the concept that conditions of life—the physical and social environment—are basic factors in the development of chronic disease.

**INFECTION.** It has been known for many years that pathogenic organisms are the causative agents in certain chronic diseases, e.g., syphilitic aortitis, diphtheritic heart disease, rheumatic heart disease, neuromuscular residuals of poliomyelitis, neurological sequelae of encephalitis, and gonorrheal arthritis. Within the last few years the occurrence of some cases of congenital heart disease—formerly considered to be a nonpreventable disease—has been shown to be related to rubella infection in the mother during pregnancy, particularly during the first trimester.

The control of the infectious diseases, which are responsible for organic impairment of the heart and other organs of the body, is an important phase of chronic disease prevention.

**OCCUPATIONAL EXPOSURES.** The influence of specific environmental factors in causation of cancer is well established (Hueper, 1950). Carcinogenic agents have been identified in a number of occupations. Men employed in certain chromate and uranium ore operations have vastly higher mortality rates from lung cancer than is usual for men of their age. Cancer of the bladder is much more common among amine dye workers than among the general population. Radiologists show a mortality from leukemia (due to exposure to x-radiation) which is much higher than expected. Exploration of the effect of conditions of work on the development of cancer and other chronic diseases has only begun.

**NUTRITION DEFICIENCIES AND EXCESSES.** Nutritional deficiency is well known as an etiologic factor in several chronic disease processes. Insufficient iodine in food results in thyroid disease. In some instances of iodine deficiency heart disease results, either myxedema or thyrotoxicosis. Severe deficiency of thiamine may lead to cardiac decompensation in the form of beriberi heart. Recent studies indicate that lipotropic factors in the vitamin B complex (choline, inositol) may be related to the deposition of fat in the intima of blood vessels (atherosclerosis).

Table 19-2. Standardized death rates<sup>1</sup> for specified causes of death, all ages combined, by weight class<sup>2</sup>

Cause of Death	Standardized Death Rate per 100,000					
	Underweight		Normal Weight	Overweight		
	15-34%	5-14%		5-14%	15-24%	25%+
All causes	913	833	844	1,027	1,215	1,472
Organic heart diseases	63	66	80	115	135	129
Angina pectoris	12	14	16	32	39	37
Diseases of the arteries	15	17	23	34	46	41
Acute and chronic nephritis	56	64	82	108	202	224
Cerebral hemorrhage and apoplexy	46	50	70	101	115	170
Diabetes	9	9	14	22	45	117

<sup>1</sup> Rates are per 100,000 population.

<sup>2</sup> Based on mortality experience of about 200,000 insured lives.

Abstracted from Table 48, page 195, L. I. Dublin, A. J. Lotka, M. Spiegelman, *Length of Life*, The Ronald Press Co., New York, 1949.



Not only undernutrition but also overnutrition is related to chronic disease. General caloric overnutrition (obesity) is closely associated with excessive mortality from several chronic diseases. Table 19-2 reveals that the greater the degree of obesity, the higher the death rate from the following: organic heart disease; other vascular diseases, including cerebral hemorrhage; nephritis; and diabetes. Persons with marked obesity (more than 25 per cent above normal) have more than 12 times the mortality rate from diabetes than persons slightly underweight. For cerebral hemorrhage and apoplexy the differential is three times, for nephritis almost four times and for organic heart disease approximately two times. Even a slight degree of obesity, 5 to 14 per cent above normal, has a considerable effect. In fact, it will be noted that the so-called "normal weight" persons have a higher mortality from these diseases than those who are "underweight." This fact naturally raises the question as to whether "normal" weights—which merely represent arithmetic means—should be considered optimum weight. So far as mortality from chronic disease is concerned Americans are on the average overweight. Reduction of obesity and the maintenance of optimum weight is a major element in the prevention of chronic disease in the United States.

**EMOTIONAL DISORDERS.** Emotional patterns resulting from social maladjustments are being given increasing recognition as possible etiologic factors in chronic disease. One cannot consider the problem of obesity, for example, without noting that it is often a manifestation of emotional disturbance. The role of the emotions in the causation of vascular and other diseases is now being intensively explored.

**SOCIO-ECONOMIC STATUS AND CHRONIC DISEASE.** Available data show marked variations in mortality rates among different socio-economic groups. In point are the studies by the Registrar General for England and Wales in which standardized mortality rates were computed for the population classified into five socio-economic groups (see Table 19-3). For cancer of the stomach and esophagus among males aged 20-65, the professional workers (Group I) have the lowest mortality rates and the unskilled workers (Group V) have the highest rates. The rates for cancer of these sites in unskilled workers are approximately twice that in professional workers.

Similar mortality rate patterns are found for pulmonary tuberculosis. In contrast, for coronary heart disease significant differences in the opposite direction are shown among the socio-economic groups, with Group I having the highest rates and Groups IV and V the lowest.

A study by J. S. Whitney of death rates by occupation in 10 selected states of the United States in 1930 also revealed marked variation in mortality among different occupational groups. Standardized death rates from specified causes per 100,000 gainfully occupied males 15 to 64 years of age are shown in Table 19-4.

The fact that socio-economic status is related to the prevalence of chronic disease has been demonstrated not only in mortality statistics but also in disability statistics. In the National Health Survey reports data are presented (U. S. Pub. Health Service, 1938) on the number of days of disability per person per year (per capita volume of disability) for certain diseases, by income status. The per capita volume of disability from rheumatism among persons aged 20-64 was more than four times as great among the lowest income group (persons on relief) as among the highest (persons with incomes of \$5,000 and over). A similar comparison for the

Table 19-3. Comparative incidence of social class and occupation mortalities in various cause groups<sup>1,2,3</sup> England and Wales, 1950<sup>4</sup>  
Deaths Registered (1950) per 100 Calculated Standard Deaths at Age 20-65

Occupation—Social Class		All Causes	Respiratory Tuberculosis	Cancer (all sites)	Cancer of Buccal Cavity, Pharynx	Cancer of Esophagus, Stomach	Diabetes	Vascular Lesions of Central Nervous System	Chronic Rheumatic Heart Disease	Arterio-sclerotic (Coronary) Heart Disease	Myocardial Degeneration	Nephritis
I All occupied and retired men		100	100	100	100	100	100	100	100	100	100	100
II Professional, etc.		97	64	96	157	67	167	123	61	150	67	128
III Intermediate between I and III		86	62	84	90	69	97	102	87	110	82	93
IV Skilled workers		102	103	105	96	100	97	104	103	104	97	101
V Intermediate between III and V		94	95	94	100	111	91	81	102	79	98	87
Unskilled workers		118	149	110	110	131	108	100	114	89	137	112

<sup>1</sup> The rate for all occupations being taken as 100 in each case.

<sup>2</sup> Deaths classified according to International List of Causes of Death, 1948 edition.

<sup>3</sup> Rates underscored are calculated on less than 50 deaths.

<sup>4</sup> Deaths in 1950 related to population figures derived from the 1951 Census one percent sample tables.

Source: "Occupational Mortality, Part I," *Registrar General's Decennial Supplement, England and Wales, 1951*, Table 4, p. 11.



Table 19-4. Standardized<sup>1</sup> death rates from specified causes per 100,000 gainfully occupied males, ages 15-64, in selected occupations, selected states,<sup>2</sup> 1930

Occupation	All Causes	Diseases of the Heart	Tuberculosis of the Respiratory System	Cancer and other Malignant Tumors	Diabetes Mellitus
All gainfully occupied males	909.8	175.3	87.5	81.7	12.1
Professional men	670.5	177.0	26.2	70.3	10.9
Proprietors, managers, and officials	792.5	184.2	43.2	81.0	16.2
Clerks and kindred workers	775.2	185.5	65.8	77.7	13.5
Agricultural workers	623.2	95.9	46.5	56.2	9.4
Skilled workers and foremen	828.9	166.0	72.1	85.4	10.9
Semiskilled workers	1009.3	199.5	102.1	90.8	13.2
Unskilled workers	1447.7	243.0	184.9	106.6	12.5

<sup>1</sup> Standardized according to age distribution of all gainfully employed males in 10 selected states.

<sup>2</sup> Alabama, Connecticut, Illinois, Kansas, Massachusetts, Minnesota, New Jersey, New York, Ohio, and Wisconsin.

From J. S. Whitney, *Death Rates by Occupation*, National Tuberculosis Association, New York, June 1934, p. 32.

cardiovascular diseases shows three times as much disability among those in the lowest income level.

In seeking interpretation of the relation of socio-economic status to chronic disease it is evident that socio-economic status embraces a complex array of factors—occupation, nutrition, housing, medical care, education, habits of living, personal hygiene, etc. The relation of these factors to chronic disease merits further investigation.

**Prevention.** As yet our knowledge of the etiology of the chronic diseases is only fragmentary. This basic fact must not obscure other equally significant facts. With the existing though limited knowledge of etiologic agents and of factors associated with chronic disease we can prevent the occurrence of a significant number of cases of some of these diseases; we can prevent an appreciable amount of disability; and we can postpone, if not prevent, death from certain of these diseases. Through the application of existing knowledge about specific carcinogenic agents, infective processes and nutritional factors, the occurrence of a certain amount of chronic disease can be prevented. After onset—in diseases such as cancer, diabetes, several forms of cardiovascular disease, neuromuscular and other chronic diseases—much can be done to prevent illness and disability through early diagnosis and adequate treatment, including intensive rehabilitation.

Prevention of chronic disease is not solely a responsibility of the physician. Rather it is the responsibility of society as a whole. However, the physician should elucidate the relationship between chronic disease and the conditions of life and modes of living. By directing public attention to the importance of changing those conditions which give rise to disease, he can fulfill an important part of his social obligation to prevent disease.

## CARDIOVASCULAR DISEASES

Diseases of the heart and blood vessels—the cardiovascular diseases—are a group of conditions of diverse etiology linked together because they affect principally one organ system. They constitute the leading causes of death and of disabling illness in the United States.

**Mortality Trends.** In statistical grouping of causes of death, it is customary to combine chronic nephritis with the cardiovascular diseases. In 1950, deaths attributed to the cardiovascular-renal diseases totalled 769,751 in the United States (U. S. Dept. H. E. W., 1955). Of this number, 70 per cent were ascribed to diseases of the heart, 20 per cent to intracranial lesions, 3 per cent to nephritis, and 7 per cent to other forms of vascular disease.

As a cause of death the cardiovascular diseases appear to have advanced sharply in recent years. It is difficult to interpret this trend for the separate diseases because of the numerous changes in nomenclature and classification. A case which three decades ago might have been called chronic nephritis is now labeled hypertensive heart disease. Advances in diagnostic standards have also altered the picture. Hence in considering the *trend* of mortality over the years, it is necessary to lump the cardiovascular and renal diseases together.

At present approximately one out of every 200 persons in the United States dies each year as the result of a cardiovascular-renal disease. These diseases now account for one half of all deaths; in 1900 only one fifth of all deaths were due to these diseases. However, this significant change in proportional mortality (Table 19-5)

Table 19-5. Cardiovascular-renal diseases—crude death rates, proportionate mortality, and age-adjusted death rates, United States Death Registration States, 1900-1950 <sup>1</sup>

Year	Crude Death Rate per 100,000	Proportionate Mortality (percentage of all causes of death)	Age-adjusted Death Rate per 100,000 <sup>2</sup>
1950	511	53.0	439
1940	487	45.4	487
1930	420	37.2	502
1920	371	28.6	485
1910	382	26.0	504
1900	353	20.5	453

<sup>1</sup> The Death Registration Area did not include all states until 1933. Therefore, data for previous years do not represent mortality for total United States.

<sup>2</sup> Adjusted by the indirect method on the basis of the age distribution of the United States population, 1940.

Source: Office of Biometric Research, National Heart Institute, *Statistics of the Cardiovascular Diseases*, January, 1950, Tables 1 and 2, pp. 1 and 2. Public Health Service, Publication No. 429, *Cardiovascular Diseases*, 1955, Tables 14 and 15, pp. 27 and 28.

during the past 50 years is attributable largely to the increasing percentage of older persons in the population.

When correction is made for the age changes in the population it is evident that the death rate from the cardiovascular-renal diseases (age adjusted) is actually declining. There has been a downward trend since 1930. Whereas the risk of dying



from these diseases in any one year remained relatively constant from 1910 to 1930, there has been a 12 per cent decline in the past two decades.

The downward trend in the cardiovascular-renal disease death rate has not been uniform among the various age groups of the population. Table 19-6 reveals that

Table 19-6. Cardiovascular-renal diseases—deaths and age-specific death rates, United States  
Death Registration States, 1920-1950 <sup>1</sup>

Age (in years)	1920	1930	1940	1950
All ages				
Deaths	319,590	493,046	642,783	769,751
Rate	371	420	487	511
Less than 45				
Deaths	43,168	53,850	48,135	39,140
Rate	64	60	50	36
45-64				
Deaths	93,417	151,077	188,086	214,189
Rate	650	730	721	706
65 and over				
Deaths	183,005	288,139	406,562	516,422
Rate	4,398	4,462	4,508	4,213

<sup>1</sup> The Death Registration Area did not include all states until 1933. Therefore, data for previous years do not represent mortality for total United States.

Bureau of the Census, *Vital Statistics Rates in the United States, 1900-1940*, Table X, p. 1008.

Bureau of the Census, *Mortality Statistics, 1920*, Table 7, p. 272.

Bureau of the Census, *Mortality Statistics, 1930*, Table 7, p. 232.

Bureau of the Census, *Vital Statistics of the United States, 1940*, Table 11, p. 210.

Source: Public Health Service Publication No. 429, *Cardiovascular Diseases, 1955*, Table 2, p. 5. Office of Biometric Research, National Heart Institute (mimeo.), *Statistics of the Cardiovascular Diseases*, Jan. 1950, Table I, p. 1.

for persons under 45 years of age the death rate has been decreasing sharply; for middle-aged and older persons it has been stationary.

The types of heart diseases most common in the early decades of life result from infectious processes, especially rheumatic fever. In the older age groups, the effects of arteriosclerosis are relatively more frequent. The decreasing mortality from cardiovascular-renal diseases among younger persons is probably due in large part to a decrease in the frequency and severity of the bacterial diseases affecting the heart, e.g., the streptococcal infections. The incidence of these bacterial diseases has been decreasing over a long period extending back to the latter part of the nineteenth century. Improved standards of living, as well as specific control measures, may account for this long-term trend. With the recent developments in chemotherapy even greater control of these disease processes can be expected.

Comparable progress has not been made with respect to the cardiovascular diseases common in later life. However, medical research has recently demonstrated significant relationships between metabolic factors and some of these diseases, suggesting the possibility of further reduction in mortality from this cause.

**Morbidity.** Current data on cardiovascular disease morbidity are not available. From the National Health Survey (1935-1936) data, it has been estimated that there were 9,200,000 persons in the United States with cardiovascular-renal diseases as of July 1, 1949. Estimates indicate that more than 100,000,000 days are lost from work or other usual pursuits each year by reason of cardiovascular disease (U. S. Public Health Service, 1939).

Only limited information is available on the relative prevalence of the major types of heart disease. Data, from a study made in 1939 of 4,547 cases seen in 19 cardiac clinics in Philadelphia, are shown in Table 19-7. As found in this study,

Table 19-7. Heart disease (all forms)—percentage distribution of etiological types of heart disease among 4,547 cases <sup>1</sup> in 19 Philadelphia heart clinics, spring of 1939

Etiological Type <sup>2</sup>	Percentage of All Cases
Total—all types	100.0
Rheumatic heart disease	35.0
Arteriosclerotic heart disease	20.1
Hypertensive heart disease	12.5
Syphilis of aorta and heart	4.4
Congenital heart disease	4.3
Thyroid heart disease	0.6
Other organic heart disease	8.2
Functional cardiac conditions	0.4
Potential and possible heart disease	14.5

<sup>1</sup> Consists of 3,869 cases of organic heart disease and 678 cases with functional cardiac conditions or possible heart disease.

<sup>2</sup> Listed according to primary etiological type.

Abstracted from Table 4, pp. 7 and 8, in Hedley, O. F., "Heart Disease in Philadelphia Cardiac Clinics," *Public Health Bulletin*, No. 268, U. S. Public Health Service, 1941.

rheumatic heart disease accounted for about one third of all cases, arteriosclerotic and hypertensive heart disease for another third, and miscellaneous conditions, including potential and possible heart disease, for the rest.

**Prevention of Occurrence. CONGENITAL HEART DISEASE.** Until very recently, congenital heart disease was regarded as nonpreventable. A certain number of pregnancies resulted in "blue babies" or infants with other manifestations of cardiac defects. The cause of these malformations was not known. However, research in the last few years has revealed that many cases of congenital heart disease, and other congenital defects such as blindness and deafness, are due to antepartum rubella infection (see section on rubella, Chapter 1) in the mother, particularly during the first trimester of pregnancy.

Just a few years ago the diagnosis of severe congenital heart disease meant, in most cases, a fatal prognosis. Modern surgery has changed this outlook. Diagnostic and surgical technics recently developed now permit the saving of many children whose hearts and large blood vessels are congenitally defective.

For maximum utilization of these new technics, active case-finding programs are necessary. Parents, teachers, public health nurses, and others should be made aware of the advances in this field, and be assisted to recognize the early signs of congenital heart disease in children. These include cyanosis, breathlessness, chest



deformity, and clubbing of the fingers. Children with these symptoms should be referred to their own physician. Final diagnosis and treatment of such children often require highly competent teams composed of physicians who see enough cases of heart disease in children to maintain their skills at a high level. In many parts of the country, centers are being established to which physicians may refer cases of suspected congenital heart disease for adequate study and treatment. In view of the highly specialized nature of resources necessary for handling congenital heart disease and the relatively small number of cases, the development of such centers appears to be the best way of meeting the problem.

**INFECTIOUS FORMS OF HEART DISEASE.** A variety of infections may damage the heart, as noted in the section on mortality trends. However, these are becoming less common as causative agents. Diphtheritic heart disease, once a fairly frequent complication of diphtheria, is now a rarity.

Syphilitic heart disease has declined in importance as the frequency and severity of this disease has decreased and better methods of treatment have been made generally available (see section on syphilis, Chapter 4).

Bacterial endocarditis is a fairly frequent complication of rheumatic valvular disease and congenital heart disease. It may follow dental surgery and surgery of the nose or throat. To protect against this infection which formerly was fatal in almost all cases, antibiotics are administered before and immediately after such surgery in the presence of valvular or congenital heart disease. In this manner the occurrence of bacterial endocarditis is prevented in many instances. Patients with valvular or congenital heart disease should be carefully instructed that their disease requires special precautionary measures before any such surgery is undertaken.

Rheumatic fever (see streptococcal infections and rheumatic fever, Chapter 1) is the most prevalent type of infectious heart disease. It is a repetitive disease, recurring again and again in the same child with increasingly serious damage to the heart muscles and valves. Rheumatic fever attacks or recrudescences are usually associated with recent streptococcal infections. This relationship has been obscured by the fact that the onset of rheumatic fever is often insidious. It may follow the streptococcal infection by two to six weeks or longer. From several recent studies, it appears that prompt and adequate treatment of acute streptococcal infections with penicillin is effective in reducing the risk of subsequent rheumatic fever.

Once rheumatic fever has occurred, patients are often placed on continuing chemotherapy or antibiotic therapy to prevent recrudescences. Daily doses of sulfa compounds have been commonly used. However, this regimen necessitates very close medical observation, including laboratory studies so as to minimize the danger of reactions to these drugs. Oral penicillin has been proved equally effective and is much safer. It has come into increasing use as the cost declined and better means of administration worked out, until it is now the drug of choice for rheumatic fever prophylaxis.

Not only is the rheumatic child himself likely to suffer recurring attacks of the disease, but his siblings are also subject to a much higher attack rate than are children in nonrheumatic families. Hence, once rheumatic fever has struck any member of a family, preventive care should be directed toward the entire family.

Environmental factors play a significant, though not precisely defined, role in initiating rheumatic fever and in the perpetuation of the disease. Overcrowding and other manifestations of poor economic status have been clearly linked with high

incidence and repetitiveness of rheumatic fever. Serious attention should, therefore, be given to improving the housing, nutritional and emotional aspects of the patient's environment. The medical social worker can contribute a great deal in these respects toward preventive care in rheumatic fever. For example, the physician in recommending a single bed, or a room alone, for the rheumatic child will often find that the medical social worker can provide assistance to the family in carrying out such advice.

The full classical picture of rheumatic fever with obvious signs of acute infection, severe joint pain, and carditis is not often seen. Much more frequently the onset of the disease is vague. It may escape attention for months or even years. Yet damage to the heart valves in these "mild" cases may be profound. Hence, active case-finding endeavors, aimed at bringing all suspicious cases to medical attention, are an essential feature of the prevention of disability and death from rheumatic fever. Awareness by physicians of the possible significance of even vague symptoms is an important aspect of early case finding. But the medical profession is not alone in this responsibility. Parents, teachers, and public health nurses should be alert to the potential danger of such signs as nontraumatic epistaxis, abdominal and precordial pain, joint pain, pallor, anorexia, lassitude, and failure to gain weight. The schoolroom provides an excellent opportunity to detect such symptoms. Adequate referral arrangements for diagnosis and care should, of course, be available and used.

In conclusion, for the prevention of rheumatic fever, prompt chemotherapy or antibiotic therapy of streptococcal infection, especially in siblings of known cases, is recommended. And, after onset, vigorous early case finding by physicians, continuing chemoprophylaxis or antibiotic prophylaxis of known cases, and attention to socio-environmental factors are recommended to reduce disability and death from this disease.

The effectiveness of ACTH and cortisone in rheumatic fever is now being studied. Prompt suppression of the clinical manifestations of the disease has been achieved. So great is the promise of this new form of therapy that the possibility of a fundamental change in our entire approach to the problem of rheumatic fever must be considered.

In a summary review of heart disease due to infectious agents, it is appropriate to emphasize these points. During recent decades there has been a sharp drop in this type of cardiovascular disease. Present knowledge if effectively applied should lead to a virtual disappearance within the next decade of heart disease resulting from diphtheria, syphilis, rheumatic fever, and other infective agents. In the United States, such an accomplishment would largely eliminate cardiovascular disease as a cause of death and disability in the first half of life.

**HYPERTENSIVE AND ARTERIOSCLEROTIC CARDIOVASCULAR DISEASE.** In general, it must be said that the etiology of hypertension is little understood, even though some mechanisms in the pathogenesis of hypertension have been discovered, e.g., the humoral mechanism associated with renal ischemia.

Three factors known to be associated with the hypertensive disease process offer the physician some possibility of dealing with the problem on preventive basis. These factors are: a definite familial tendency, the relationship of obesity to hypertension, and the personality pattern of hypertensive patients.

When hypertension has occurred in one or several members of a family, addi-



tional cases among siblings and children of patients may be anticipated. Whether this is due to hereditary factors or to patterns of living is not clear. In any event, the physician, especially if he serves the entire family, should be alert to early manifestations of the disease in all members of the family.

Obesity is highly correlated both with morbidity and mortality from hypertension. Reduction of weight in the obese-hypertensive patient has been shown to result in a lowering of blood pressure. It may reasonably be assumed that maintenance of optimum weight, especially where a familial tendency to hypertension is known, will assist in keeping the blood pressure at more normal levels. Achievement of this aim often requires personality adjustment, since overeating may be a manifestation of an emotional disorder.

The fact that psychic factors sharply affect the cardiovascular system, including the blood pressure, has been clearly demonstrated. Sharp but temporary increases in blood pressure occur with anxiety, fear, or anger. From this fact and the fact that the pressure is often labile during the early phases of hypertension, it has been hypothesized that long-continued psychic trauma to the cardiovascular system results eventually in sustained hypertension and its structural concomitants. Psychological studies of hypertensive patients suggest that personality disorders, characterized by suppressed hostility, are associated with the disease. The avoidance or correction of such personality defects through good mental health may prevent the development of hypertension. Interesting case studies have been published illustrating the apparent reversal of early hypertension through psychotherapy. However, much more work in this field must be carried out on large series of cases before the role of this factor in the prevention of hypertension can be evaluated.

As in the case of hypertension, our knowledge of the etiology of arteriosclerosis is quite meager. It has long been known that the intimal thickening in arteriosclerosis is due to deposits of fat, including cholesterol. Recent studies in this field offer convincing evidence that this condition is closely associated with specific disorders of metabolism. There is strong hope now that arteriosclerosis may be prevented or corrected when metabolic factors are better understood. This new optimism contrasts sharply with the old fatalistic view that arteriosclerosis represented an uncontrollable "degeneration" of aging.

The most promising of these recent studies are exploring the relationship between coronary artery disease and abnormal cholesterol metabolism, especially hypercholesterolemia. Patients with coronary thrombosis have, on the average, substantially higher blood cholesterol levels than persons without evidence of coronary disease. It has been demonstrated that lowering of blood cholesterol levels exerts a favorable effect on arteriosclerosis in animals. Numerous studies now in progress are designed to elucidate the relationship of cholesterol to the occurrence of arteriosclerotic disease in humans, and the possibility of preventing the disease through control of fat metabolism.

Whether hypercholesterolemia can be reduced through dietary control is still unsettled. It is known that the body synthesizes some cholesterol through ordinary processes of metabolism even though no foods high in cholesterol value are ingested. Some studies on apparently normal human populations have revealed no significant relationship between consumption of cholesterol and blood levels. Other studies,

especially of patients with coronary disease, have indicated that lower blood cholesterol levels may be attained on low cholesterol diets.

According to recent work (Boas and others, 1948), a hereditary disorder in the metabolism of cholesterol (resulting in hypercholesterolemia) is associated with coronary artery disease. Siblings of patients with coronary artery disease show a high incidence of hypercholesterolemia and of coronary artery disease, especially at the younger age levels.

Another recent finding is that coronary arteriosclerosis is associated with a particular fraction of the blood cholesterol (Gofman and others, 1950). This fraction may be amenable to dietary control through low cholesterol foods, but more investigation of this question is required before final judgment can be made.

In summary, recent data suggest the possibility of preventing arteriosclerotic cardiovascular disease through maintenance of low blood cholesterol levels. Low cholesterol diets may be important in this regard. Administration of substances which reduce cholesterolemia is another possibility, especially where coronary artery disease is impending or exists. These measures have been proposed particularly in the presence of obesity or familial history of arteriosclerotic disorder. Critical evaluation of these measures is needed.

**Prevention of Disability and Death.** Since our knowledge of how to prevent the occurrence of hypertensive and arteriosclerotic heart disease is still quite limited, cases of these diseases will continue to occur. However, even after their onset, prevention of disability and premature death is possible in many instances.

Early diagnosis of these conditions by the physician creates the best opportunity for minimizing their progress toward disability and death. Although these diseases are ordinarily first discovered in the physician's office, many cases can now be detected in mass screening programs. The 70 mm. chest x-ray film usually taken for the discovery of tuberculosis can also be interpreted for abnormal size or contour of the heart shadow. About 2 per cent of the general population over the age of 15 years screened in one chest x-ray survey showed suspicious cardiac findings. Intensive follow-up of these persons revealed that about one half of them (1 per cent of the total group screened) had previously unknown, clinically significant heart disease (Thompson and Jellen, 1948). In other surveys, the percentage with suspicious findings on the screening film has varied from 0.5 to 3.5 per cent.

Mass chest x-ray screening programs offer an excellent opportunity for finding heart disease. Up to the present such programs have been insufficiently utilized for the detection of heart disease.

Proper management of patients with hypertensive and arteriosclerotic heart disease will not only prolong their lives but make them happier and more productive. Several approaches should be used, including proper diet, reduction of excess weight, emotional re-education, and occupational adjustment. Recent successes with salt-restriction, anticoagulant therapy and drugs such as methonium, hydralazine and reserpine offer a considerably improved prognosis even to the patient with severe disease.

The place of emotional re-education in preventing disease and premature death from hypertensive and arteriosclerotic cardiovascular disease is not adequately defined. Certainly the personality pattern must be considered in correcting obesity. Excessive eating often reflects underlying emotional needs which should be met in



some other manner. The cultivation of serenity is especially important for persons with cardiovascular disease. Merely telling the patient "be calm" or "stop worrying" is of little avail. The patient must be assisted in developing insight into his emotional problems if any effect is to be expected. A noteworthy point in psychologically supportive therapy is that not all patients with hypertension or with definite arteriosclerotic disease die quickly under ordinary conditions of stress. Some live many years of practically normal life with apparently no further manifestation of disease, a fact insufficiently stressed in the education of the patient. Further evaluation of the role of psychotherapy in cardiovascular disease is needed.

A frequently important aspect of prolonging useful life of patients with cardiovascular disease is occupational adjustment (Goldwater, 1947). Balance must be maintained between unnecessarily condemning the individual to invalidism on the one hand and ignoring the need to lighten his labor on the other. The ideal solution is selective job placement, consistent with the physical capacity of the patient. The problem of adequate job placement for persons with cardiovascular disease is complicated by employment policies which preclude the hiring of handicapped persons and discourage the retention of such persons in employment. Restrictive employment policies were adopted originally on the theory that the quality and output of work by physically handicapped persons is inferior to that of nonhandicapped persons. Although mounting evidence indicates this theory to be untenable, restrictive employment policies persist because of other considerations. Workmen's compensation rulings, conditions in employer liability insurance, and plans for disability retirement in industry militate against the employment of persons with cardiovascular disease. Here is another illustration of the effect of social conditions on the management of disease. The physician in caring for the patient with cardiovascular disease must extend his interest beyond the patient and his individual pathology.

Maintenance of optimum weight, emotional adjustment, and suitable job placement are important in the reduction of disability and premature death from hypertensive and arteriosclerotic heart disease.

## CANCER

Cancer may be defined as a group of diseases characterized by an abnormal growth of cells which spread through the tissues of the body. It is synonymous with the terms malignant neoplasm. Its properties of invasiveness and metastasis differentiate cancer from benign neoplasms which do not have such properties. However the dividing line between malignant and benign neoplasms is not sharp.

Malignant neoplasms may originate in practically any tissue or site of the body. A variety of cellular types is involved, including epithelial cells (carcinoma), connective tissue cells (sarcoma), and blood cells (leukemia). Ultimately, it may be demonstrated that these are different diseases.

**Mortality.** Cancer is now second among the leading causes of death in the United States, accounting for approximately 200,000 deaths (one eighth of all deaths) each year. The number of cancer deaths and the corresponding crude death rate have been increasing sharply in recent years, as indicated in Table 19-8. The crude death rate has just about doubled in the period 1900 to 1950.

Examination of the rates for the two sexes reveals a striking difference in trend.

Table 19-8. Cancer—deaths, crude death rates, proportionate mortality and age-adjusted death rates by sex, United States Death Registration States, 1900-1950 <sup>1</sup>

Year	Deaths	Crude Death Rate per 100,000	Proportionate Mortality (Percentage of All Causes of Death)	Age-Adjusted Death Rate per 100,000 <sup>2</sup>		
				Total	Male	Female
1950	193,977 <sup>3</sup>	128.7	13.4	115.0	117.1	113.2
1940	158,335	120.0	11.2	119.6	114.8	124.9
1930	114,186	97.4	8.6	113.4	101.6	126.2
1920	71,756	83.4	6.4	104.9	88.8	122.5
1910	36,193	76.2	5.2	97.0	77.3	118.2
1900	12,769	64.0	3.7	79.6	60.1	99.2

<sup>1</sup> The Death Registration Area did not include all states until 1933. Therefore, data for previous years do not represent mortality for total United States.

<sup>2</sup> Adjusted on the basis of the age distribution of the population enumerated as of April 1, 1940.

<sup>3</sup> Leukemias and cancers of lymphatic and hematopoietic tissues (International List Numbers 200-205) are excluded from 1950 deaths and death rates to make the rates comparable with earlier years. The Sixth Revision of International List of Causes of Death, 1948, made these diseases a part of the neoplasm classification for the first time.

Source: Public Health Service, *Vital Statistics of the United States, 1950*, Table 8:43, p. 210. Federal Security Agency, *Cancer Mortality in the United States*, "Trend of Cancer Mortality in the United States, 1900-1945," Vol. 32, No. 1, December 28, 1949, Tables 1, 2, 3, pp. 11, 12, 13.

The age-adjusted cancer mortality rate for females in the United States reached a peak about 1930 and since that time has been steadily dropping. The rate for males, on the other hand, continued to climb at least until the 1940's.

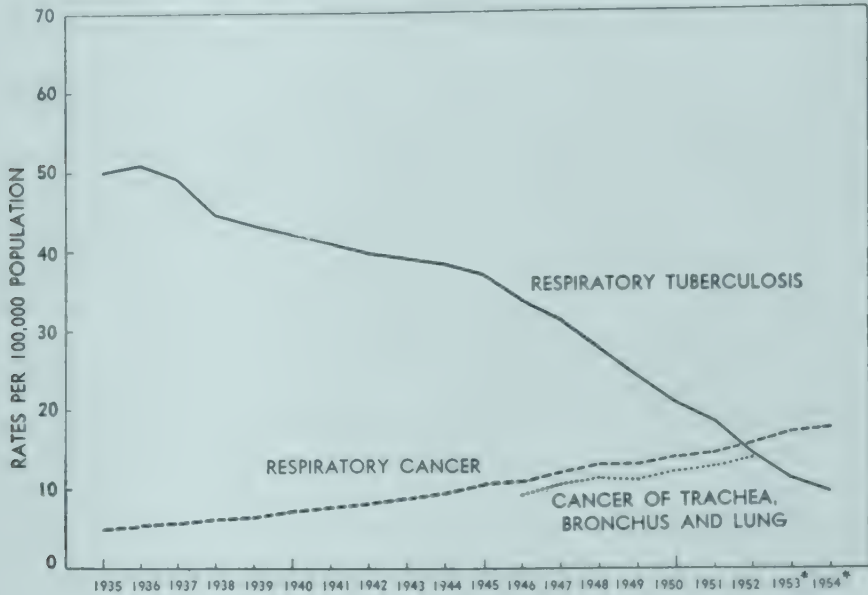
**Factors in Mortality Trends.** Two major factors must be considered in interpreting the rapid increase in the total number of cancer deaths. One is the aging of the population, for which accurate correction can be made in the rates. However, even when correction is made for age, there remains a substantial increase—more than 50 per cent during the same period—not attributable to changes in the age composition of the population. The other element is the improvement in diagnostic standards, a factor which does not lend itself to precise measurement. However, because our ability to diagnose cancer has improved considerably during recent decades, it is reasonable to assume that some part of the rise in age-adjusted cancer death rates is due to this factor.

The decline in cancer mortality among females (Table 19-8) may be attributed in part to earlier diagnosis and more effective treatment of cancer of the accessible sites, which comprise a substantial proportion of cancer in women. This decline represents a significant sign of progress in cancer control.

Among males, part of the steady rise in cancer mortality is due to the rapid increase in cancer of the respiratory tract during recent years, especially cancer of the lung. Although it is true that some of this increase is due to improved methods of diagnosis, autopsy records of several leading hospitals reveal that the proportion of lung cancer diagnoses to all diagnoses has risen sharply in recent years. This finding suggests that there has been an absolute increase in cancer of the lung. Figure 19-2 shows trends of mortality from pulmonary cancer and pulmonary tuberculosis in males in the United States. It is evident that there has been a crossing of the curves; more persons in this country now die from respiratory cancer than from respiratory tuberculosis.



Deaths from cancer of the skin, lip, and buccal cavity—all accessible sites, and more common as sites of cancer among males—have been decreasing in recent years. Earlier recognition and more adequate treatment of cancer of these accessible sites are responsible in some degree for this downward trend. Improved oral hygiene, such as elimination of jagged teeth through better dental care, may also have played a role.



Source: Bureau of the Census, U.S. Pub. Health Service, Nat. Office Vital Statistics.

Fig. 19-2. Death rates from respiratory tuberculosis and respiratory cancer, 1935-1954, and cancer of the trachea, bronchus and lung, 1946-1952, United States. (By place of occurrence, 1935-1941; by place of residence, 1942-1954.)

\* 10 per cent sample.

**Morbidity.** Data on the prevalence of cancer in the United States are limited. Dorn and Cutler (1955) on the basis of surveys during 1948-1949 in 9 metropolitan areas in various parts of the country, found a prevalence rate of 430 per 100,000. From the same study it was estimated that 319 new cases per 100,000 persons are diagnosed for the first time during each year (incidence rate).

Distribution of cancer by site is indicated in Table 19-9. Cancer of the digestive tract accounts for about one third of all cancer among males, but less than one fourth among females. Cancer of the respiratory tract, urinary system and buccal cavity is much more prevalent among males than females. Almost one half of all cancer in females develops in the breast or genital system, sites which in most instances are accessible to early recognition—a fact of particular significance in cancer control.

**Distribution in Population Groups.** Significant age, sex, geographic, race, and socio-environmental differences in cancer mortality have been noted.

In general, cancer prevalence increases with age. Cancer of the prostate occurs most commonly in men past the age of 65 years. The prevalence of cancer of the breast rises sharply during the late middle years of life and continues to rise in the later years of life. However, cancer of the brain is much more likely to develop in

Table 19-9. Primary site of development of cancer among white males and females <sup>1</sup>

Primary Site <sup>2</sup>	Male	Female
Trachea, bronchus and lung	9	2
Urinary system	7	3
Buccal cavity	5	2
Skin	15	11
Digestive Tract	32	23
Breast and genital system	12	45
All other sites	20	14
Total	100	100

<sup>1</sup> Percentage distribution of standardized rates for all ages using the total population of the United States, 1950, as standard.

<sup>2</sup> The classification of the primary site of cancer follows the Sixth Revision, International List of Causes of Death.

From Dorn, H. F., and Cutler, S. Jr., "Morbidity from Cancer in the United States, Part I," *Public Health Monograph No. 29*, U. S. Pub. Health Service, 1955, p. 28.

the early years of life, and cancer of the bone and leukemia are found in infants and children.

For sites common to both sexes, there is more cancer among males than among females. Cancer of the stomach causes almost twice as many deaths among men as it does among women. In cancer of the lung, the ratio of male to female deaths is four to one. These differences may reflect varying degrees of exposure to carcinogenic agents rather than biological sex differences. The fact that deaths due to cancer of the esophagus and stomach are more common among persons of low economic status (see Table 19-3) also suggests some extrinsic (socio-environmental) factor.

In the southern part of the United States cancer of the skin occurs much more commonly than it does in the northern states. This difference has been attributed to heavier solar radiation in the south. Solar radiation, in the 2,900 to 3,200 Å range, is an experimentally demonstrated carcinogen (Blum, 1940).

Negroes in the United States have far less cancer of the skin but considerably more cancer of the uterine cervix than do Caucasians. The difference in skin cancer probably reflects biological variation in amount of skin pigment. Among Caucasians themselves, those with darker skin show less skin cancer than fair-skinned persons.

In the case of cervical cancer, however, all available evidence indicates that extrinsic factors, rather than biological variations, are responsible for the "racial" differences. Cervical cancer is known to occur more frequently among women who have experienced several pregnancies than among those who have had none. It also appears that pregnancy early in life may predispose to the development of cervical cancer. Many studies show a higher mortality from cervical cancer among persons of lower economic status than among the higher income groups. To such factors—multiple pregnancies especially early in life and low income status—we can probably attribute the higher incidence of cervical cancer among Negroes than among whites.

Apparent "racial" and "geographic" differences in the occurrence of cancer deserve careful scrutiny. They may conceal underlying socio-environmental variations among groups of people, including differences in the amount and quality of medical care.

Socio-environmental factors in the development of cancer have only recently



begun to receive the attention they merit. According to British statistics cancer of the esophagus and stomach causes twice as many deaths among persons in the lowest economic group as among the highest. Skin cancer is highly correlated not only with certain occupations but also with social status and exposure to soot and grime. Similarly, in cervical cancer as noted above, environmental conditions may be responsible factors.

A relatively new approach—the epidemiologic investigation of cancer, with emphasis on social causation—offers much promise of providing information useful in the prevention of cancer. It may lead to isolation of more specific etiologic agents.

**Etiology.** In spite of the vastly increased research into the nature of cancer during the recent years, our understanding of the specific etiology of cancer is advancing slowly. This is perhaps due to the fact that cancer is not a single clear-cut disease entity. Rather, it appears to be a group of diseases characterized by abnormal cellular growth. Hence, research is necessary both into the cell (and its various types) and into the factors that precipitate the cellular abnormality.

Three general categories of etiologic factors have received the greatest attention—genetic, endogenous, and exogenous. Although individual studies are usually designed to isolate one or another specific factor in these groups, the possibility that they are interrelated must be constantly kept in mind.

The genetic theory received its greatest support from the fact that strains of small animals have been developed with proneness to cancer of certain sites. In one strain cancer occurs in a very high proportion of offspring. Another strain of the same species, apparently living under the same conditions, shows cancer only occasionally. The genetic theory has been challenged recently by the discovery that excessive incidence of breast cancer in a certain strain of mice was due to an ultra-microscopic factor transmitted through the milk. Formerly this strain was considered one of the classical demonstrations of the operation of some chromosomal mechanism. However, Bittner demonstrated that “cancer prone” mice, when foster-nursed by mothers of a low cancer-incidence-strain, did not develop the disease. On the other hand mice from so-called noncancer strains, when suckled at the breasts of mothers from a cancer strain, did show a high incidence of breast cancer. The development of cancer was apparently due to some ingested factor.

Endogenous changes, i.e., alterations in physiology, have also been suggested as factors in the development of cancer. It has recently been demonstrated that administration of female sex hormones to men with cancer of the prostate results in substantial improvement and prolongation of life—though not cure. Likewise, male sex hormones given to women with breast cancer often produce significant but temporary improvement. Comparable results are obtained through castration. From such evidence, it appears that hormonal balances are concerned in perpetuation and extension of these two types of cancer. Possibly, changes in secretion of the sex glands during middle and later life are responsible for the original neoplasm itself. It is conceivable that other endocrine glands play some role.

That exogenous factors directly cause some cancers has been known for many years. For example, cancer of the scrotum among chimney sweeps—noted in England during the days of the Industrial Revolution—was caused by long-continued exposure to soot. Protection against such exposure prevented cancers in this occupational group.

Since that time a great variety of agents have been demonstrated to be carcinogenic. Several types of carcinogenic agents are listed below:

1. Mechanical (cancer of the buccal cavity and lip due to jagged teeth and pipe stems).
2. Chemical (cancer of the bladder due to certain aniline dyes; leukemia due to benzol poisoning; cancer of the lung due to chromate ores).
3. Thermal (cancer originating on the site of old burns).
4. Radiation:
  - A. Solar (cancer arising on the exposed parts of the skin among outdoor workers).
  - B. X-radiation (cancer of the lung among Schneeberg miners due to contact with radioactive ores; cancer in x-ray burns; and leukemias among radiologists).
5. Parasitic (cancer of the bladder due to infection with *Schistosoma hematobium*).

A tremendous variety of agents, therefore, possess the property of stimulating malignant growths. However, the total proportion of cancer cases which have been clearly demonstrated as due to specific carcinogens, is not great. One difficulty in establishing such a relationship is that it is often concealed by a long latent period, even 10 to 30 years. Occupational and other exposures at the time the cancer is diagnosed may be irrelevant. It is not customary in the United States to obtain and record carefully socio-environmental information in connection with morbidity and mortality. Detailed epidemiological studies of cancer patients, with particular attention to their exposures throughout life, would be likely to yield valuable information. The discovery of carcinogenic agents and other factors associated with cancer incidence, prepares the way for prevention of at least certain types of cancer.

**Prevention of Occurrence.** When specific carcinogens have been identified (as in certain occupations) every effort should be made to eliminate the exposure or at least to reduce such exposure to the minimum. In industry, this requires knowledge of toxic materials; design of machinery and organization of processes so as to prevent access of the carcinogen to workers; good housekeeping; and adequate disposal of carcinogenic wastes. During periods of rapid expansion of chemical industries, as in wartime, insufficient attention is given to such problems.

Education for individual responsibility in avoiding exposure to known carcinogenic agents is also of considerable importance. Numerous illustrations of this type of cancer prevention could be cited; self-protection of radiologists against leukemia and skin cancer; avoidance of excessive exposure to solar radiation, especially by fair-skinned persons who are more likely to develop cancer of the skin; improvement of oral hygiene, including attention to jagged teeth and to other forms of chronic irritation.

The discovery and treatment of precancerous lesions constitute a second important realm of cancer prevention. Keratoses of the skin; warts subject to chronic irritation, e.g., plantar warts; solitary thyroid adenomata; fibroadenomata of the breast in young women; chronic cervicitis; leukoplakia; and chronic gastritis (pernicious anemia type) are examples of lesions and chronic processes known to be associated with subsequent cancer development. Physicians may prevent a substantial amount of cancer mortality by noting such lesions, explaining their potential



significance to the patient, and taking whatever corrective action is indicated. Individuals known to have exposure to carcinogens, such as workers in certain industrial operations, should have periodic examinations for the purpose of discovering any precancerous changes. In the case of the aniline dye industry, for example, cystoscopic examinations at six-month intervals have been used to reveal alterations in the bladder mucosa. If abnormalities are found removal from further exposure and continued observations are ordered so as to minimize the danger of cancer morbidity and mortality.

Improvement of general standards of living and health may be expected to reduce the incidence of cancer of some sites. A relationship has been noted between cancer of the skin and occupation; cancer of the cervix and low economic status; cancer of the buccal cavity and poor dental care; and cancer of the stomach and low economic status. Better working conditions and more adequate medical and dental care would contribute to the reduction of cancer.

The occurrence of cancer may, therefore, be prevented through: (1) identification and avoidance of carcinogenic agents; (2) systematic discovery and treatment of precancerous lesions; and (3) improvement of the general standards of living.

**Prevention of Disability and Deaths.** Since our knowledge of how to prevent the occurrence of cancer is so incomplete, major efforts in cancer control must continue to focus on early diagnosis and adequate treatment of the case. After the onset of cancer, a substantial number of patients' lives are being saved and more could be saved.

Approximately one fourth of all patients admitted to hospitals in the United States for the diagnosis and treatment of cancer are being "cured," i.e., they survive at least five years following treatment, without evidence of recurrence. It is recognized that even after the five-year mark has been passed some patients develop recurrences of the original disease. Such instances are frequent enough to justify indefinitely continued follow-up examinations.

A wide range of rates of cure have been published. These rates vary depending on the types of treatment used, the nature of the cases comprising the series, and other factors. The over-all approximate figure of 25 per cent survival from cancer, given above, is based upon the recent experience of several states which have maintained a follow-up of patients treated in a variety of types of hospitals.

The over-all cancer survival rate masks wide differences in survival rates for cancer of different sites and different stages. Table 19-10 shows the extent of this variation among four sites, in California experience.

Table 19-10. Cancer--five-year survival rates by site, according to stage at first admission, 1942-1946

STAGE	NUMBER IN EACH GROUP					PER CENT 5-YEAR SURVIVAL				
	Total	Prostate	Lung	Ovary	Breast	Total	Prostate	Lung	Ovary	Breast
Localized	1,139	25	6	17	153	51	36	0	52	73
Regional	2,553	120	110	57	426	18	18	0	25	31
Metastasis	3,541	236	290	162	377	8	8	0	1	25
Unknown	6,186	482	272	100	305	28	26	7	45	50
Total	13,419	863	678	336	1,261	23	20	3	21	39

Source: State of California Department of Public Health, Tumor Registry

Since the time when the patients represented in these survival percentages were actually treated, considerable progress has been made in diagnosis, and in radiation and surgical technics. It is likely, therefore, that survival of cancer patients is steadily improving. For example (Symposium, 1948), among patients treated for cancer of the breast in 1938 at Memorial Hospital in New York City, 28.8 per cent survived five years. Of those admitted during 1942, the corresponding survival percentage was 39.8. A report (Symposium, 1948) from Washington University School of Medicine, St. Louis, reveals that since the first pneumonectomy for lung cancer was performed in 1933, this type of surgery has been performed on 311 patients. Of these, 52 were operated on before 1942 with a five-year survival rate of 28 per cent. In the early days of this surgical procedure for lung cancer, operative mortality was 53 per cent. It has subsequently been reduced to 7 per cent. Thus, in less than 20 years, a formerly hopeless disease is now being treated successfully in a significant percentage of cases.

So rapid have been the advances in cancer diagnosis and treatment that—according to most authorities—an estimated one third of the present deaths from cancer could be avoided through application of present knowledge. In the United States this would mean saving approximately 70,000 lives annually. Accomplishment of this goal depends primarily upon two factors: (1) early detection and diagnosis; (2) prompt and adequate treatment.

In the promotion of early diagnosis and treatment of cancer public education is a most important element. A recent nation-wide survey (University of Michigan, 1948) showed that although 80 per cent of the population considered cancer one of the most dangerous diseases, only 60 per cent knew that it was curable and only 49 per cent could name a single symptom of cancer. Acquaintance of the public with the common symptoms of cancer should be encouraged. This can be accomplished by individual education of patients by physicians as well as by public campaigns. Even after suspecting the presence of cancer, some persons delay seeking medical attention because they fear having their suspicion confirmed, or because they do not know or believe that cancer is curable in the early stages. Both recognition by the patient and motivation are therefore needed.

Besides public education several other specific methods have been suggested and tried for the early detection of cancer. These include: various forms of periodic examinations by physicians, and mass screening tests carried out by technicians.

A complete physical examination including a careful history every year or even every six months has been advocated as one means of detecting cancer. Special examinations can be carried out in physicians' offices or in cancer detection centers where apparently well people report periodically for check-ups. These examinations have two well-recognized values: (1) the discovery of cancer in from 0.2 to 1.0 per cent of the population examined, depending upon the nature of the population and the completeness of the investigation; and (2) the discovery of a significant amount of other disease which had not been recognized previously. (From some detection centers as many as 50 per cent of the persons examined have been referred to physicians for necessary attention for a variety of conditions.)

Detection centers have served one other important purpose, i.e., to stimulate public and professional interest in the idea of periodic examinations. The popularity of detection centers is attested by the fact that applicants have had to wait weeks



or months for appointments at many of the centers. The popularity of these centers probably reflects, to some extent, the difficulties experienced by people in finding physicians who will do comparable examinations in their own offices. Recognition of this situation by the medical profession has led to the recent proposal to "make every doctor's office a cancer detection center."

The fact that complete examinations are quite expensive in terms of physician time and laboratory services has led to certain modifications. One is to limit the investigations to a few accessible sites such as the skin, buccal cavity, breast, cervix, and rectum. A check of these areas can be performed rapidly and—it will be recalled—these sites account for more than one half of all female cancer and a substantial amount of male cancer. These sites are also the ones most amenable to cure in the present state of our knowledge.

Another approach to the problem of early cancer detection has been the application of cytology and radiography in mass screening programs.

Since many cancers originate in epithelial tissues (carcinoma) they begin at an early stage to exfoliate cells with the morphologic characteristics of malignancy. If recovered, such cells may constitute the earliest manifestation of cancer. They are present in many cases before any detectable lesion appears. The technic of recovering, staining, and examining such cells is known as the cytologic test for cancer.

This test was developed and has been applied most extensively for cancer of the cervix. Many reports indicate a discovery rate of two to four cervical cancers per 1,000 apparently well women screened with the cytologic test. It should be emphasized that these were women with no signs or symptoms of cancer. Often the final diagnosis was carcinoma in situ, i.e., cancer confined to the normal boundaries of the tissue in which it originated.

The cytologic technic is also used in the detection and diagnosis of pulmonary cancer. For this site, sputum specimens have been found to be approximately as reliable as bronchial washings (Farber and others, 1950)—an important factor in the use of the test on a mass scale for detection of pulmonary cancer. Its use is advocated in all pulmonary disease not obviously due to some other cause. Some institutions use the test routinely in tuberculosis wards. It would also appear useful in follow-up of persons screened by mass chest x-ray surveys and found to have suspected pulmonary disease. Attention is again drawn to the fact that in the recent years mortality from lung cancer has increased to the point that it now exceeds mortality from pulmonary tuberculosis in the United States.

Application of the cytologic test of cancer to gastric, prostatic, and other specimens is now being studied.

The miniature films taken in mass x-ray surveys may disclose pulmonary cancer as well as tuberculosis and heart disease. Intensive follow-up of neoplasm suspects from such surveys, including adequate arrangements for diagnosis and treatment would result in the saving of a considerable number of lives. Increasing attention is being given to this aspect of mass x-ray surveys.

Mass application of radiographic techniques for the discovery of cancer of the upper gastro-intestinal tract is now being evaluated. One proposal has been to carry out a preliminary screening of older age males by determining the presence of achlorhydria, occult blood in the stool, or pernicious anemia. Those who show positive findings are given radiographic examinations. Work is also in progress in

the development of a technic suitable for mass use for making quick but permanent records of the radiographic appearance of certain parts of the gastro-intestinal tract.

In the fight against needless deaths from cancer, many forces are now being joined. Patients are seeking medical attention earlier in the course of this disease. Growing numbers of persons are availing themselves of health examinations in physicians' offices and cancer detection centers. Physicians have become increasingly alert to the early signs of cancer and great progress is being made in diagnosis and treatment. To assist in the early detection of cancer, physicians, voluntary and official health agencies, and other groups are cooperating in programs of public and professional education and in the development of mass screening services, incorporating such procedures as photofluorography and cytology. Research workers, although concentrating on the etiology of malignant growths and on ways to prevent the occurrence of cancer, are also deeply concerned with prevention of disability and death following the occurrence of cancer. Extensive research is under way to find new diagnostic and therapeutic technics, e.g., serologic tests for the diagnosis of cancer and the use of radioactive substances in diagnosis and therapy.

The forces arrayed against needless deaths from cancer share this common motivation—existing knowledge and technics can save the lives of tens of thousands of cancer patients each year.

## DIABETES

Diabetes is a constitutional, hereditary, metabolic disease characterized by high blood sugar levels and excretion of sugar in the urine. It is associated with a relative insulin insufficiency. It is not clear whether this insufficiency is due to deficient production or diminished effectiveness of the hormone secreted by the islands of Langerhans in the pancreas. Insulin insufficiency is closely related to abnormal activity of other glands of internal secretion, especially the pituitary.

Diabetes is important not only for its acute derangements of body chemistry which may lead to fatal acidosis and coma, but also, because it predisposes to the development of arteriosclerosis, neuritis, and cataract.

**Mortality.** The number of deaths attributed to diabetes has risen sharply since 1900, as has the crude mortality rate (Table 19-11). During the period 1900 to 1950, the proportion of all deaths charged to diabetes increased severalfold, and the disease advanced to appear among the 10 leading causes of death. For 1950, the mortality rate from diabetes was 16.2 per 100,000, according to the revised method of coding causes of death. However, the rates are much higher among older age persons (Iskrant and Kurlander, 1955)—over 100 per 100,000 for persons 65 years of age and older, 25 per 100,000 for those in 45-64 year age group, and less than 1 per 100,000 among children. Females are affected more frequently than males.

One may wonder why the discovery of insulin in 1921 and its widespread use has not resulted in a reduction in diabetes mortality. Insulin does not cure diabetes; it merely helps to control the disease. When the patient ultimately dies from some other cause, diabetes is usually still present and is listed on the death certificate, even though it may be well controlled. Until 1949, the statistical allocation of causes of death was based on arbitrary coding rules. One effect of such rules was that if diabetes was mentioned on the death certificate, it took a high priority for assignment



Table 19-11. Diabetes—deaths, crude death rates, proportionate mortality, and age-adjusted death rates, United States Death Registration States, 1900-1950<sup>1</sup>

Year	Deaths	Crude Death Rate per 100,000	Proportionate Mortality (Percentage of All Causes of Death)	Age-Adjusted Death Rate per 100,000 <sup>2</sup>
1950 <sup>3</sup>	24,419	16.2	1.7	14.3
1950 <sup>4</sup>	(42,102)	(27.9)	(2.9)	(24.7)
1940	35,015	26.6	2.5	26.6
1930	22,345	19.1	1.7	22.2
1920	13,898	16.1	1.2	19.8
1910	7,252	15.3	1.0	18.9
1900	2,187	11.0	0.6	13.0

<sup>1</sup> The Death Registration Area did not include all states until 1933. Therefore, data for previous years do not represent mortality for total United States.

<sup>2</sup> Adjusted on the basis of the age distribution of the United States population, 1940.

<sup>3</sup> Actual number of deaths as coded by Sixth Revision, International List of Causes of Death, 1948. This revision in coding changed the death rate markedly and requires an adjustment before comparing with earlier years.

<sup>4</sup> Estimated number of deaths and death rates in 1950 if coded by the Fifth Revision of the International List. See Vital Statistics of the United States, 1950, Vol. I, p. 182.

Source: Public Health Service, Vital Statistics of the United States, 1950, Vol. I, Table 8:43, p. 212; Bureau of Census, *Vital Statistics—Special Reports*, Vol. 23, June 26, 1945, p. 26; Vol. 16, August 4, 1942, p. 65; *Ibid.*, *Vital Statistics Rates in the United States*, 1900-1942, p. 872.

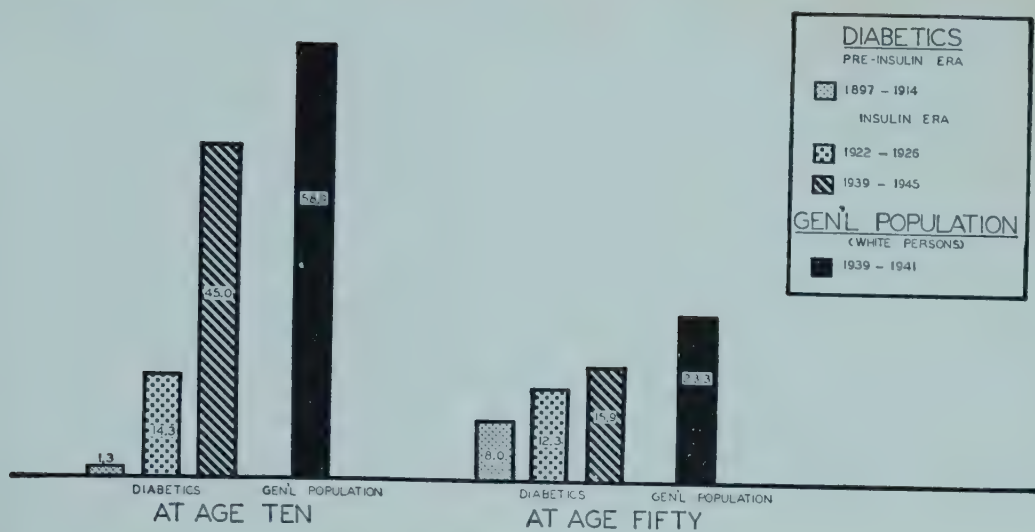
as the primary cause of death. Thus, many persons who died with diabetes had their deaths attributed to diabetes, although the actual cause of death may have been quite unrelated to it.

In 1949, a new method of coding death certificates was adopted in the United States. According to this new method, the death is charged to whatever disease the physician indicates is the primary cause. Diabetes is thus not arbitrarily selected. It appears that there will be an almost 50 per cent drop in the diabetes mortality rate due to the change in method of coding death certificates. The new method will reflect the true cause of death more accurately. However, its adoption means that caution must be exercised in comparing current figures on diabetes mortality with those of previous years.

Because of these difficulties, diabetes mortality statistics are not as significant as similar statistics for cancer and for cardiovascular-renal disease.

Another and more meaningful view of the trend of death from diabetes may be obtained by comparing the expectation of life for known diabetics who were under care at different periods during the past 50 years. Figure 19-3, based upon data from the George F. Baker Clinic for Diabetics in Boston, Massachusetts, reveal that a diabetic 10 years of age in the period 1897-1914 had a life expectancy of only 1.3 years; in 1939-1945 a 10-year-old diabetic had a life expectancy of 4 years. This phenomenal improvement in the outlook for a child with diabetes may be attributed largely to the use of insulin. Even at the age of 50 years, there has been a doubling of life expectancy during the past half century. In fact, such excellent means have been developed for controlling diabetes that the expectation of life for persons with the disease is rapidly approximating that for the general population.

**Morbidity.** Field studies of the prevalence of diabetes during the past few years have radically changed our concept of the amount of diabetes in the American popu-



From Joslin, Elliot P., and others, *Postgrad. Med.*, 5:2:139, 149.

Fig. 19-3. Expectation of life in years for diabetics,\* and for white persons in the general population. Selected ages and periods.

\* Seen at the George F. Baker Clinic, Boston.

lation. As recently as 1946, Marks estimated on the basis of extensive studies that there were 700,000 diabetics in the United States, with 55,000 new cases occurring each year (Marks, 1947). A year later (1947), a survey was made in Oxford, Massachusetts, by the U. S. Public Health Service (Wilkerson and Krall, 1947). This survey, which included blood sugar and urine sugar tests for 70.6 per cent of the entire population of Oxford (4,983 persons), disclosed 70 cases of diabetes. Of these, 40 were previously known cases and 30 were previously unknown, i.e., were discovered in the survey. If the percentage of cases discovered in the surveyed population is projected to the entire population, the resulting prevalence rate would be 1.7 per cent. Assuming that this rate is applicable to the country as a whole, it can be estimated that more than two million persons in the United States have diabetes, and about one million of them are unaware of the disease.

**Factors in Occurrence.** That there is an hereditary susceptibility to diabetes has been known for many centuries. The incidence of diabetes is several times higher among the parents and siblings of diabetics than among the parents and siblings of nondiabetics. In part, this higher incidence may be attributed to familial patterns of living, such as excessive eating. However, from studies of twins convincing evidence is available as to the hereditary factor in the disease. For homozygous (identical) twins, where one of the pair has diabetes the incidence of diabetes among the paired siblings ranges from 49 to 100 per cent, depending upon the age of the subjects at the time of the study (White and Pincus, 1946). This may be compared with an incidence, among heterozygous (fraternal) twins of diabetics and among nontwin siblings, of 5 to 10 per cent.

While heredity determines susceptibility to diabetes, the actual occurrence of the disease among adults is correlated with obesity. According to Joslin more than one half of the diabetics in his series at some time during their life were 20 per cent or more above average weight. Table 19-2 in the introduction to this chapter indicates the excessive mortality from diabetes which is associated with obesity. Obesity



may be the basis for the higher incidence of diabetes among upper income groups. Conversely, the lower incidence among persons engaged in heavy manual labor may be associated with relative undernutrition.

**Experimental Diabetes.** Animal experimentation has not only yielded an effective treatment for diabetes but may yet lead to methods of prevention. Diabetes has been produced in animals by several techniques, including injection of alloxan; pancreatectomy; prolonged administration of glucose-in-saline solution intraperitoneally; and partial pancreatectomy plus injection of anterior pituitary extract. Diabetes produced in cats by the latter method can be cured if treated with insulin during the first three months after onset of the disease (Lukens and Dohan, 1942). Functional recovery of animals is maintained after insulin therapy is discontinued. These experiments are consistent with the theories that diabetes may result from overtaxing the insulin-producing mechanism and that it may under certain conditions be reversible. The restoration of function to the islands of Langerhans in animals apparently depends upon the initiation of treatment early in the course of the disease.

**Prevention of Occurrence.** Since heredity is involved in the development of diabetes, consideration must be given to the possibility of preventing it through the restriction of marriage among diabetics. The marriage of known diabetics to one another should be avoided since the disease would probably appear in their offspring (Joslin and others, 1946). Marriage of diabetics into families where diabetes is common may result in a high proportion of offspring with diabetes. However, the marriage of a diabetic to a nondiabetic whose family is free of the disease apparently does not predispose to diabetes in their children. Among diabetics, birth control as well as restriction of marriage should be considered for the prevention of diabetes in children.

The achievement and maintenance of optimum weight is a significant factor in preventing diabetes. Dietary control is especially important in families where diabetes is common. Frequently, glycosuria and hyperglycemia are reduced and even eliminated when there is a significant reduction of weight in obese middle-aged persons. In one study (Paul, 1941), 127 obese females over the age of 45 years with slightly to strongly positive sugar tolerance tests were advised to stay on reduction diets. Among 10 patients who did not reduce their weight, five subsequently showed signs that the disease process had progressed, i.e., two "potential" diabetics became true diabetics, and in three diabetics the disease became severe enough to require insulin. Among the 117 patients who did succeed in lowering their weight, 94 per cent showed improvement in sugar tolerance.

For the prevention of diabetes, especially if the disease is present in the family the following measures are recommended: (1) avoid obesity; (2) if already overweight, reduce weight to optimum; (3) have periodic examinations for the presence of urine sugar and high blood sugar levels; (4) avoid intermarriage of diabetics.

**Prevention of Disability and Death.** The considerable extension of life expectancy for diabetics in recent years has been due largely to better patient management including the use of insulin. The earlier treatment is started, the more likely it is to be effective.

The detection of diabetes in its earliest stages—before the onset of typical symptoms which often reflect advanced disease—and continuing good care are basic elements in the prevention of disability and death from diabetes. The preventive

significance of early detection of diabetes is twofold. Discovery of the disease in its presymptomatic state, if followed by adequate treatment, minimizes the danger of complications such as coma and infection. In addition, from laboratory and clinical evidence it appears that early therapy reduces the progress of the disease process itself and may even reverse the pathologic changes. Diabetics with no or minimal complications at the time of diagnosis have a death rate less than one-third that of patients with serious complications at the time of diagnosis (Metropolitan Life Ins. Co., 1949). Another indication of the fact that good care saves diabetics is the fact that physicians with diabetes show a lower mortality than nonphysicians with the disease, especially in the younger age groups.

Since the disease occurs more commonly in families where one member is known to have it, emphasis in case finding should be placed on detecting the disease in parents, siblings and the children of known cases. Periodic examinations of members of families where diabetes exists constitute an important element in the control of the disease.

Until 1947, the principal method for the early discovery of diabetes was urinalysis. Reliance was placed on this technic because it was believed that substantially all early diabetics showed glycosuria. Also, the Folin-Wu method of blood sugar determination, requiring venous blood, was too cumbersome and expensive.

Wilkerson, Heftmann, and their associates in the U. S. Public Health Service have developed and popularized a new method of detecting diabetes. It is based upon use of 0.1 ml. capillary blood from the finger tip or ear lobe for a simple inexpensive blood sugar test. The specimen is collected within two hours after a meal containing at least 50 grams of carbohydrate. The test can be completed within five minutes. It reveals only whether the blood sugar is above or below a certain level. Community-wide surveys utilizing this test and urinalysis have demonstrated the feasibility of the blood sugar screening method. They have also shown that about one out of three diabetics escape detection if dependence is placed upon a single urine specimen. Both blood and urine sugar tests should be used for maximum results.

Screening examinations, using blood and urine sugar tests, may be carried out on a routine basis in physicians' offices, hospitals, and in community-wide surveys. Concentration on members of diabetic families will yield the greatest return per 1,000 persons examined. However, application of this procedure to large population groups is required if a substantial proportion of the million undiscovered diabetics in the United States today are to be found.

Once diabetes is diagnosed, it becomes important that a close and friendly relationship between the patient and his physician be maintained. Diet, and the use of insulin if necessary, must be regulated. Special emphasis must be placed upon the avoidance of infections which may precipitate a crisis in the disease. Good hygiene of the feet, including cleanliness and avoidance of pressure, is important because of the vascular changes which so frequently occur. Since the giving of detailed instructions in hygiene and diet for diabetics is so time consuming, efforts have been made to organize such teaching in group classes. In one community such classes have achieved considerable success (Wilkerson, 1949).

As in the case of other diseases, a successful attack on diabetes will require the wholehearted cooperation of the public, medical and allied professions, voluntary health agencies, such as the American Diabetes Association, and health depart-



ments. The focal point of this attack should be the discovery of diabetes in its early stages. Treatment is now often delayed until symptoms of advanced disease have appeared. Intensive management of diabetes from its incipency not only reduces disability but also offers hope for restoration of pancreatic island function.

### NEUROMUSCULAR DISABILITY

Neuromuscular disability is a general term embracing a wide variety of conditions which limit the voluntary muscular capacities. Some of these defects are congenital, e.g., cerebral palsy. Others are residual effects of neutropic virus infections such as poliomyelitis. Trauma accounts for a large group including amputees and paraplegics. Probably the largest number result from diseases of obscure etiology such as rheumatism, multiple sclerosis, and epilepsy. Among older age persons a common disability is hemiplegia arising from intracranial lesions of vascular origin.

**Mortality and Morbidity.** Although the primary condition—such as virus infection or cerebral vascular lesion—may result in death, the neuromuscular conditions themselves are not significant causes of mortality. Rheumatism, for example, is rarely mentioned on the death certificate as a contributing cause of death.

However, these diseases account for a large amount of disability. Rheumatism alone, according to the National Health Survey (1935-1936) in the United States, affected almost 7,000,000 persons and caused approximately 100,000,000 days lost from usual employment; it is by far the most prevalent pathological condition. Other diseases in the neuromuscular group, while not as common as rheumatism, often result in long-term disability and even permanent invalidism when they occur. Any period of life may be affected: infancy (cerebral palsy); childhood (poliomyelitis); young adult life (multiple sclerosis and rheumatoid arthritis); and old age (cerebral vascular lesions).

Neuromuscular disability is an important cause of economic as well as physical dependency. It often requires long-term medical and institutional care so that the personal and family resources are exhausted. A substantial proportion of persons receiving governmental financial assistance in the United States, especially during periods of favorable economic circumstances, consists of families where one or more members suffer from a neuromuscular handicap.

**Prevention of Occurrence.** Aside from accident prevention and vaccination for poliomyelitis, knowledge of specific measures for the prevention of occurrence of the diseases and conditions which cause neuromuscular disabilities is quite limited.

**Prevention of Disability.** During the past decade there has begun an important shift in public and professional attitudes toward treatment of this handicapped group. Previously, they were among the most neglected of health problems. Three influences have contributed to the development of more aggressive and optimistic viewpoints. The first was the pressure for manpower during the war years which led to the large-scale introduction of handicapped persons into industry. Although they had heretofore been largely cast aside by industry, these handicapped individuals proved their worth in production and their records showed an absentee rate no greater than that of normal persons. Second, physical medicine—encouraged by opportunities in the armed forces and in civilian life—demonstrated its ability to improve significantly the physical capacities of persons formerly considered helpless.

Finally, clinical investigation has led to the use of drugs which offer great promise in controlling such diseases as rheumatoid arthritis and epilepsy.

During the war years, 1941-1945, industry was forced to expand even though the labor reservoir was diminished due to simultaneous expansion of the armed forces. Employment of handicapped persons became a necessity. Experience with such persons dispelled many misconceptions about their work performance, e.g., false beliefs that they have a higher accident rate or that their work performance is poor. In a study by the U. S. Department of Labor, Bureau of Labor Statistics (1948), the records of matched handicapped and nonhandicapped workers exposed to the same work hazards were compared. There were no significant differences between the two groups in rates of absenteeism and frequency of nondisabling injuries. The handicapped, given reasonable job placement, had a lower rate of disabling injuries and their production rate was better than that of normal workers.

Data such as the above led the Association of Casualty and Surety Executives, composed of 65 major companies, to adopt a policy that no higher rate for workmen's compensation insurance is charged because of employment of disabled workers (Wilbur, 1946). Not only large industry, but small plants also have found the employment of physically impaired workers to be economically sound. In fact, several successful small plants have been established largely on the basis of utilizing handicapped persons.

Expanding employment opportunity for persons with neuromuscular disabilities has been a major factor stimulating rehabilitation efforts. There had been some interest in rehabilitation following World War I. However, major emphasis was on vocational training and guidance, and little attention was given to physical restoration until the past decade.

During and since World War II, the success of physical medicine in dealing with the problems of the disabled has been a second important influence toward an improved outlook for those with neuromuscular handicaps. A dynamic approach—stimulation of patient activity—has replaced passive care and proved the value of vigorous attack on these problems. An example of the results of aggressive treatment of patients with such disorders by physical medicine at a Veterans' Administration hospital is quoted in a report of the Council on Physical Medicine and Rehabilitation of the American Medical Association (1949). Of 130 patients all except two were World War I veterans and many had not been out of bed in 10 years. After nine months of a rehabilitation program 65 of the patients had been discharged to their homes, and 25 of these were employed. Of those remaining in the hospital 30 were ambulatory and undergoing advanced rehabilitation, and 25 were capable of some self-care. All but 10 of the original group of 130 had shown significant improvement.

A report (Federal Security Agency, 1947) of the first fiscal year (1945) of operation of the expanded Federal-State Vocational Rehabilitation Program for civilians disclosed that services were provided for 161,047 persons of whom 41,925 completed their services and obtained jobs. Many of the others were still in process of rehabilitation at the end of the year. Of the group rehabilitated into jobs, 79 per cent were unemployed at the time of applying for services, and 18 per cent had never worked previously. Their income, including wages and subsistence, before rehabilitation was approximately \$12,000,000 per year. After rehabilitation they earned at the rate of \$73,855,700 per year. They returned through income taxes to



the Federal Government in the first year after rehabilitation about two thirds of the cost of their rehabilitation services.

Both technical and organizational advances in physical medicine have helped to make possible such excellent results. Technical advances include emphasis on active motion by the patient against resistance, instead of assisted motion and massage; improved prostheses which are designed primarily for function rather than appearance (e.g., "hooks" instead of "hands"); training equipment and programs which stress self-care and independence as the first steps in rehabilitation, thus minimizing an attitude of dependence upon others. Organizationally, it has been recognized that centers for rehabilitation offer the best prospects for successful efforts. In such centers can be concentrated the specialized medical and auxiliary personnel as well as equipment. After diagnosis and evaluation a planned program for each patient can be undertaken with medical direction and including participation by physical therapists, occupational therapists, medical social workers, and other professional workers.

The recent development of several drugs has also improved the outlook for those with certain types of neuromuscular disabilities. Probably the most striking advance has been the use of ACTH and cortisone in rheumatoid arthritis. Dramatic, though temporary, improvements occur regularly in persons with this disease when either substance is used. When the drug is discontinued relapses ensue. How to maintain improvement and yet avoid undesirable side effects with these drugs is a problem still to be solved.

The control of epilepsy has been greatly enhanced by such drugs as dilantin, mesantoin, and tridione. Skillful use of these substances, singly or in combination with phenobarbital, greatly reduces both grand mal and petit mal seizures in most persons with epilepsy.

In summary, neuromuscular disability can be prevented or significantly reduced in many instances through physical medicine and drug therapy. Employment opportunities for individuals with such diseases have expanded and should be encouraged.

### EARLY DETECTION OF DISEASE BY HEALTH EXAMINATIONS AND BY MASS SCREENING TECHNIQUES

Early detection is a basic element in the reduction of disability and premature death from the chronic diseases. When these diseases are discovered in their early stages, the most effective use can be made of existing knowledge and techniques of treatment, patient management, and rehabilitation. Specific procedures are available for the early discovery of many of the chronic diseases. Numerous opportunities are available for applying these detection devices. Yet a vast amount of chronic illness is well advanced before it is diagnosed for the first time. The time interval between onset of the disease and adequate medical attention must be reduced if substantial progress is to be made.

Opportunities and procedures for the detection of incipient chronic diseases are discussed below. It will be noted that no single or simple solution is offered to the problem of assuring their early discovery. Health examinations are helpful, but they offer only a partial solution to the problem. Similarly, educational campaigns—early symptoms of disease and on the need of seeking medical attention early—are

useful measures, but they too reach only part of the problem. These measures require extensive supplementation. Other approaches must also be employed, particularly the recently developed plan of multiphasic screening of large population groups.

**Adult Health Examinations.** In most instances at present, chronic diseases are discovered by the patient's physician after the patient becomes aware of symptoms, and his physician carries out diagnostic studies which may require laboratory, x-ray, and consultant services. Educational campaigns designed to motivate the public to seek medical attention at the first signs of illness increase the opportunity to detect disease early. However, in many cases symptoms do not appear until the disease is well advanced. Also, early symptoms of many of these diseases are not unlike those of minor transient complaints. Many persons are inclined to ignore them. When medical attention is sought, physicians must weigh the probabilities of serious disease against the inconvenience and expense of extensive diagnostic studies. Thus, attention to symptoms does not necessarily assure the *early* detection of disease.

Recognizing the fact that many diseases are insidious in their onset, life insurance companies and medical and public health agencies began several decades ago to recommend periodic health examinations for the early detection of disease. As greater numbers of people take such examinations, there is increased opportunity to discover incipient chronic disease. The combination of a carefully taken history, complete physical examination, and routine laboratory and x-ray studies, plus special studies which may be indicated by the history and physical examination—these elements comprise the ideal method.

The advantages of health examinations are not limited to the early detection of disease. Such examinations also serve the purpose of establishing and reinforcing good patient-physician relationships. From an interpretation of the health history, the physician may gain insight into social and environmental factors important to the patient's health. The physician is given the opportunity to review health habits and give advice concerning them. For example, the importance of oral hygiene can be stressed; women can be taught how to make self-examinations of the breast; the significance of obesity can be explained; and fallacies about health can be detected and corrected. Work capacities, both physical and psychic, can be estimated and adjustments recommended.

However desirable as an ideal, health examinations represent only a partial solution to the problem of early detection of disease. At least one hour of a physician's time is required for an adequate single examination and much more time is considered necessary by many physicians. If the review is limited to a briefer history and physical examination (as is often the case), a considerable amount of incipient disease is overlooked. Multiple routine laboratory and x-ray studies on an individual basis are very expensive. It is significant that, although the importance of health examinations has been stressed in educational campaigns and programs over the past several decades, only a relatively small proportion of the adult population has sought them.

The ideal health examination is seldom achieved. Most so-called "check-ups" are skimpy. One reason is the fact that the cost of a complete examination on an individual basis is high. Also, examinations are frequently superficial because most physicians today are oriented more toward caring for the sick than toward main-



taining health. The pressure of caring for the sick in the home, office, clinic and hospital precludes any substantial amount of time being devoted to health maintenance examinations. Obstetricians and pediatricians have succeeded to a considerable extent in directing their efforts toward health maintenance. However, it will probably be many years before this is typical of medical practice as a whole. Even though all other difficulties were overcome, at the present time there are not enough physicians in the United States to provide this type of examination for the majority of the American people. Hence, the discovery of chronic disease in the general population through health examinations has distinct limitations.

Another opportunity for the early detection of chronic disease is provided in the millions of health examinations taken for special purposes. Among these are the examinations for employment, life insurance, military service, the school health examinations, cancer detection examinations, and many others. A considerable amount of time is spent by physicians on these examinations and on completing examination forms. In most instances the examination is not performed by the examinee's family or personal physician; the people examined are not always apprised of the findings or of the need for follow-up diagnostic studies or treatment; and the examinations vary widely in scope—from the superficial "once over lightly" type of review to the extensive examination, including history, physical examination, and multiple laboratory and x-ray studies. Large segments of the population are not included in the special purpose examinations. Here again we have a valuable but limited opportunity to detect chronic disease in its early stages.

**Mass Screening Surveys.** The limitations of the "individual-examination-by-a-physician" type of approach have led workers in the fields of medicine and public health to develop supplementary measures for the early detection of significant disease in large population groups. Among these measures, the most widely known are the mass screening surveys. Millions of persons have been screened for tuberculosis in mass chest x-ray surveys and for syphilis in mass serologic surveys.

As a case-finding technic, the mass screening survey has numerous advantages. The x-ray or laboratory test can be performed by technicians. Physicians are not required to administer the tests. Physicians' services are needed only for interpretation of positive or suspicious findings and for follow-up diagnostic study of "suspects." The cost per person screened is very low; little time is required for the test and large population groups can be screened within a relatively short time. It is no surprising that these surveys have met with widespread acceptance by the medical and allied professions and by the public.

Recently, the mass screening technic has been modified significantly in demonstration programs in several areas of the country. The modification is a relatively simple one. In these demonstration programs, survey procedures are arranged to screen a population group for several diseases at one time, rather than for a single disease. Instead of a single test, a battery of tests is used in this new type of survey which is called "multiphasic screening." For example, in one multiphasic screening survey (Canelo and others, 1949), conducted jointly by a county medical society, a city health department, and a state health department, a combination of tests was used to screen for a number of diseases including tuberculosis, syphilis, certain forms of heart disease, and diabetes.

A considerable number of simple tests are now available for use in multiphasic

screening programs. The 70 mm. photofluorographic technic for detecting tuberculosis and the serologic test for syphilis are well known. Recently, there have been advances in the application of these two technics. The chest x-ray is now being interpreted not only for tuberculosis, but also for cardiac abnormalities and for pulmonary neoplasms. Where chest x-rays are so read, a considerable amount of previously undiscovered heart disease is being brought to treatment and pulmonary neoplasms are being detected in a significant number of cases, at a stage when lifesaving measures can be carried out. Further applications of the photofluorographic technic are now being evaluated, e.g., using it in combination with the Schmidt camera and contrast media for discovery of lesions of the gastro-intestinal tract.

In a recent modification of the serologic test for syphilis the specimen is collected by saturating a small amount of filter paper with capillary blood. This technic—the filter paper microscopic test for syphilis—eliminates the necessity for venipuncture. At the laboratory, only a slight alteration in the usual serologic technic is needed for the examination of the filter paper specimen.

The Wilkerson-Heftmann micro blood sugar screening test for diabetes likewise requires only a drop of capillary blood and has now been adapted to an instrument which processes automatically as many as 120 specimens per hour.

The copper sulphate method has proved satisfactory for the early detection of anemias. In this hemoglobin screening test, a drop of blood is placed in a solution and the reading is based on whether the drop rises or falls. It is thus possible from a few drops of capillary blood to screen an individual for syphilis, diabetes, and the anemias.

Urine tests for glycosuria and albuminuria are, of course, quite simple. There is no difficulty in incorporating them into a multiphasic screening procedure.

To the above tests might well be added the determination of weight and height, vision, and hearing.

Great advances have been made in the cytologic technic for the early detection of cancer. The test is now applicable on a mass scale to uterine cancer and, in combination with chest x-rays, to pulmonary cancer. Studies are being made of its applicability to gastric and other cancers. Current efforts to develop a serologic test for cancer show considerable promise.

Although it is true that no combination of x-ray and laboratory tests can take the place of a careful evaluation by a physician, it is equally true that a skillful combination of tests will lead to the discovery of a considerable number of cases of incipient disease; in many instances, cases which might be overlooked in routine "check-ups." Not only is a significant amount of early disease discovered through multiphasic screening programs, but also the physician's concern with "preclinical medicine" is greatly increased. As more persons with incipient disease are referred to him for diagnostic study and treatment, there is greater opportunity for effective guidance, treatment, and rehabilitation.

It has been pointed out that multiphasic screening is not a substitute for comprehensive health examinations and is not intended as such. It is designed specifically for the early detection of significant diseases in large population groups. In screening simultaneously for several diseases, economies are effected in the organization and administration of community-wide, industrial, and other mass case-find-



ing programs. Follow-up services—an all-important phase of case-finding programs—can also be organized and conducted more economically.

In summary, a number of opportunities for the early detection of the chronic diseases are now available. It has been noted that the "individual-examination-by-a-physician" approach requires supplementation. Mass screening surveys, and particularly those using multiple screening procedures, are valuable and economical measures for the early detection of disease (Journal of Chronic Diseases, 1955).

Multiphasic screening surveys—using various combinations of tests—are being carried on in many sections of the United States. These surveys, for the most part, are conducted jointly by the medical profession, health departments and voluntary health agencies. Their objectives include, as a main item, the evaluation of the technic itself in terms of cost factors, characteristics of population groups to be screened, screening levels for referral purposes, and essentials of organization and administration. In one area, a multiphasic screening procedure combined with a modified health examination by physicians is being studied with a view toward incorporating features of both in a community-wide health maintenance program.

Further application and critical evaluation of multiphasic screening and other technics for the early detection of chronic diseases are essential for the prevention of disability and premature death from these major health hazards in adult life.

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# 20

## MENTAL HYGIENE

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### THE PLACE OF MENTAL HYGIENE IN PUBLIC HEALTH

When public health was principally concerned with the reduction of mortality, the promotion of mental health and the prevention of mental disease could hardly be considered public health responsibilities. Aside from general paresis, few mental diseases shorten life markedly. When the reduction of morbidity was added to the aims of public health practice, however, mental illness perforce became an important concern. Patients with mental illnesses severe enough to require hospitalization occupy beds; approximately one half of the hospital beds in the United States are occupied by the mentally ill. These patients are completely unproductive for long periods of time; the half of the hospital beds occupied by the mentally ill admit only one-one-hundredth the number of patients admitted to the other half. According to the National Health Survey of 1936, mental illness was exceeded in the production of morbidity only by the arthritides. Less exact data suggest that perhaps 10 per cent of the total population is continuously ill with more or less severe types of mental illness which causes losses in social productivity and adds to the cost of medical care. Because of the size of the problem and the cost of the medical care the patients need, there is no question that mental diseases constitute a major public health problem.

The care of the mentally ill has been a governmental responsibility for centuries (Deutsch, 1949). That it did not earlier become a problem for health department is probably explained by the fact that it is such a large burden in its own right, and that it was recognized as a problem before the state began to realize its responsibility in other health areas. The hospitalization of the mentally ill is so great a problem that it has appeared to require a separate administrative department to manage it; its long tradition of separate administration makes it difficult to include it in the smaller, newer health departments, even though the latter have heavy medical care responsibilities in the case of other diseases, notably tuberculosis.

On the other hand, mental diseases have, in a limited sense, been the concern of public health since its inception. Deliria accompanying the infectious diseases were public health problems during the now fading era of the isolation hospitals. Paresis rapidly became the concern of public health when its relation to syphilis was discovered and prophylaxis against it became theoretically possible; indeed this is one of the few mental illnesses in which effective prophylaxis can be statistically demonstrated (Lemkau, 1949). Public health has recognized less responsibility for

long-term effects of complicated infectious processes. Thus, the public health officer has been concerned with the acute case of meningococcus meningitis or encephalitis but has shown less interest in the long-term behavior disorders following brain destruction or damage by these diseases. When such damage has been severe, the patients have traditionally been sent to the psychiatric hospital for care.

**The Concept of the Multiple Etiology of Disease.** When disease could be considered simply as an acute, critical battle between a host and an invading organism, ending soon in victory over the invader or in death, the explanation of the outcome could usually be made in the somewhat mechanical terms of immunology. In the more chronic diseases, however, other types of factors were found to be important. In tuberculosis, for example, there is the invasion of the host by bacteria, but the battle is not a short one and the course of the disease is not completely explained on this basis alone. Older theories of hereditary predisposition do not withstand modern critical evaluation. The course of the host-invader battle is not only a matter of the pathogenic power of the invader, but also of the "state of health" of the host. This "state of health" is not measured entirely in terms of specific immune reactions but is found to be related to more general health conditions. An important factor appears to be the psychological adjustment, the mental health, of the host. It appears that this factor in some cases, at least, determines whether or not the patient gets the disease, whether he remains under treatment once he has it, and the quality of recovery and length of time necessary for recovery. Tuberculosis is the example used here, but other chronic infectious diseases such as brucellosis, virus pneumonias and others also appear to be markedly influenced by the factor of the mental health of the host. These concepts are the subject of intensive and productive research at the present time, usually designated by the term "psychosomatics."

The occurrence of psychoses secondary to arteriosclerosis or senile degeneration of the brain does not appear to be determined by the severity of the brain damage alone, but also by the mental and social health of the whole person. This issue and its relation to the prevention of psychoses in the aged is discussed more fully below. The principle of multiple etiology, that psychological or social stress is a factor in the etiology of the psychoses as well as the brain damage, may be applied to other situations as well; for example, some of the blood dyscrasias, as well as conditions in which the brain and its nutrition do not appear directly involved. Examples of such conditions are gastro-intestinal ulceration, in either the upper or lower parts of the tract, some allergic conditions and some skin affections.

The two mental illnesses that are numerically and therapeutically the greatest problems are schizophrenia and the manic-depressive psychoses. In neither of these is any "primary" etiological factor, such as infection or brain damage, known. Both are presumed to appear because of factors of inborn vulnerability plus some other factors which place stress on the individual so that the characteristic symptoms appear. The stresses are believed to be due to life situations which are not to be defined in general terms as common to all individuals, but rather that they are specific to the particular individual affected. In other words, these two illnesses are believed to depend primarily on "host" factors, individual factors; to a large degree. It should be noted that these considerations are primarily theoretical; the hypothesis appears to serve better than any other now extant to explain the occurrence of these illnesses and to furnish a basis for the therapy, and perhaps, the prevention of them.



The situation is at present much the same in the large group of mental illnesses not requiring hospitalization. The most important group of these are the neuroses. Cause and effect relationships between factors of accumulated vulnerability and precipitating "cause" were greatly clarified through military psychiatry in World War I and II so that the multiple, nonspecific character of etiological factors in these illnesses is quite clear at the present time; so clear that few any longer question the prevailing psychogenic hypothesis in this area, a fact not so true in the case of the two major "psychogenic psychoses" discussed above.

It is quite clear that the recognition of emotion and experience factors affecting the vulnerability of the individual human being to disease excludes very few illnesses, even the acute ones. Fundamentally, the psychogenic hypothesis can be stated very simply. The health of the individual depends upon his satisfaction in living which is, in turn, dependent upon his social situation and interpersonal relationships and upon his attitudes and feelings, the latter having been determined by inborn factors to some extent, but more significantly by previous social situations and interpersonal relationships. It is against this background of state of health that the drama of all illness takes place, whether it be the determinant between life and death in pneumococcus pneumonia, the length of convalescence after an appendectomy, or the extent of disability following a transection of the spinal cord by trauma or destruction of cell groups by poliomyelitis.

The promotion of the personal and interpersonal health of the individual is not entirely a medical problem, in the narrow sense of that term. It involves all those forces having to do with how people live and feel. Thus, it includes sociology, economics, anthropology, psychology, philosophy, theology, and many other areas of investigation and learning. It comprises, in short, all human biology. Within the profession of medicine, this tremendous area of research and treatment has become one of the primary interests of the specialty of psychiatry. The sub-specialty of mental hygiene is primarily concerned with efforts and research toward the promotion of maximum health and with the prevention of disease due wholly or partly to individual or host factors, rather than to specific external, invasive etiological factors. These concepts are brilliantly discussed by Holliday (1943).

The mental health of the human being is dependent on far more than attitudes and interpersonal relationships. Mental health is impossible for the individual whose basic state of health is such that the central nervous system is hampered in its metabolism. Typical conditions of this type would be malnutrition, interferences with blood supply and various toxic states including excessive fatigue, acute or chronic. The avoidance of conditions of life which tend to lower the level of "support" received by the central nervous system is obviously mental hygiene, but mental hygiene of a very obvious and elemental sort, though by no means have all the problems of the type been solved. The problems with which the mental hygienist is principally concerned are those which are effective in conditioning toward mental ill health even in the absence of any interference with the general metabolic state of the individual.

The use of the name "mental hygiene" to designate the area of the promotion of health and the prevention of disease due to attitudinal, social and emotional factors requires some comment (Beers, 1948; Deutsch, 1949). Historically, the term has been used as an euphemism for almost all of psychiatric care and treat-

ment; indeed, when it was introduced there was little thinking beyond the reform of inadequate psychiatric hospital care and the extension of early treatment. With more modern psychodynamic concepts, the misuse of the term by confounding it with psychiatric treatment is less excusable. There are those who would like to drop the term entirely because of its historic misuse, substituting "mental health" in its stead. This is being done in many places. It is perhaps well to recognize that a proper, more restricted definition might be the object of public education rather than the merely substituting another term which, without public education as to its real meaning, will shortly become contaminated with the same issues which presently surround "mental hygiene." The prefix word "mental" could be dispensed with if medicine and the social sciences could come to a more complete realization that human biology is the basic problem, that the behavioral sciences are as much a part of the study of man as are the so-called "basic" or "pure" sciences.

**The Development of Mental Hygiene in Public Health.** When psychiatry had developed the psychodynamic hypothesis discussed above there became immediately apparent the possibility for prevention. If the life experiences of an individual so conditioned him that he became ill when further stresses impinged upon him, then it became reasonable that this early conditioning or structuring of the personality might be undone through therapy. Furthermore, the early conditioning toward liability to mental illness might be prevented by preventing some of the traumatic experiences which appear to have weakened the personality structures seen in cases requiring treatment. The experiences to be dealt with are believed to be interpersonal in character for the most part, with the parent-child relationship the most fundamental. Other conditioning factors are found in the larger social sphere beyond the family, such as the school, the church, and other community organizations. All these relationships take place in a larger sociological and cultural setting which also affects the individual's personality strength. This may happen directly as when poverty or ignorance prevents proper nutrition, or indirectly, as when the social and cultural pattern controls the kinds of persons with whom the individual comes in contact. In general, the psychogenic hypothesis holds that those experiences which take place during the periods of life marked by rapid development, infancy, childhood, and adolescence, are more influential in affecting personality structures than those occurring later.

This theory offered for the first time a practicable means of approaching the problem of the prevention of the psychogenic mental illnesses. The psychiatrist began to look for the administrative organization to reach the developing personalities in order to see whether practices could be devised which might produce a smaller number of vulnerable structures. The most pressing and immediate opportunity at the beginning appeared to be in the area of juvenile delinquency. When this problem was attacked, it was found that the cases had enormous ramifications in the community, particularly in the school. There followed a period of intense interest in pupil-teacher relationships which is still continuing, with new insights and methods in mental hygiene in the schools being developed.

Mental illness as a public health problem is no novelty in Europe, where the treatment function of public health was never so markedly separated from the preventive one as in this country, and where organized public health early took responsibility in this field. Just when and to whom the idea occurred that mental hygiene



was a public health problem in the United States is hard to determine; it was prevalent enough at the time of the first edition of the present text, in 1913, to have been given a place in it. During and immediately after World War I, the idea possessed Dr. Thomas W. Salmon (Bond, 1950), probably because he was both a psychiatrist and a medical officer in the U. S. Public Health Service and was restless enough in his thinking not to be able to keep the two aspects of his position separate. At any rate, by 1918, Welch, Howell, Rose, and others concerned with public health education considered that mental hygiene was an appropriate subject for the health officer to study, following the steps of the Harvard School of Public Health where Salmon had given courses as early as 1913.

The first state health department to establish a division of mental hygiene was, appropriately enough since this state also organized the first mental hygiene society, in Connecticut. This division was established in 1920, and in 1934 became a bureau. Not many states followed the pattern, however, until the passage of the National Mental Health Act in 1946, followed by appropriations in 1947. The "Mental Health Authority," required to be designated for each state under this act, became the health department in all but 12 of the 53 states and territories. Under the careful and creative planning and consultation service established by the Division of Mental Hygiene of the U. S. Public Health Service, later the National Institute of Mental Health, programs in states and territories have grown with exceeding rapidity (Lemkau, 1949). In 1950, all the states are working in one way or another toward the development of a program for mental hygiene and the promotion of mental health.

The first report of the Committee on Mental Health, World Health Organization, 1950, stated the importance, indeed the inevitability, of organized public health mental hygiene if there is to be any hope of controlling the tremendous cost in money and human productiveness that results from mental illness. In the words of the report: "The committee therefore considers that the most important single long term principle for the future work of WHO in the fostering of mental health is the encouragement of the incorporation into public health work of the responsibility for promoting the mental as well as the physical health of the community."

## BASIC TECHNICS IN MENTAL HYGIENE

Mental hygiene fundamentally is the effort to prevent or to change attitudes which are or are believed to be inimicable to the best possible state of health for the individual or group concerned. Attitudes are recognized to be the result of two general factors: first, the emotional experiences that have taken place in the course of a life and, second, the thinking and learning that has been done by the individual because of, or in spite of, those emotional experiences. Learning and thinking alone are easily seen to be not enough to change attitudes, viz., the deeply prejudices thinking of the learned men of the Nazi regime in Germany. These functions take place only through a screen of attitudes, what Plant (1950) has called an "envelope," a sort of semipermeable membrane which selects and colors the things learned and thought. Attitudes are, for the most part, extremely difficult to analyze by the individual who holds them, or for that matter by others, since such analysis involves prejudices and biases which are difficult to put aside. They come, some

them, from periods of life no longer within the range of memory, from the period covered by the amnesia the human has for the earliest years of his existence. The person holds certain attitudes to be axiomatic, not subject to proving, but right just because they are right; he rejects any suggestion that they are capable of interpretation on the basis of past personal experience and argues about them on some falsely logical ground, a phenomenon the psychologist calls rationalization.

A corollary to the principle that all attitudes have an emotional component, is that attitudes can be changed most effectively only when emotional forces are used in the procedure of change. An analogy to this principle might be drawn from the treatment of diabetes mellitus; the abnormal thirst is caused by a disordered metabolism which is due to lack of insulin. Giving water may quench the thirst temporarily, but to correct the disease, the disordered metabolism must be corrected by the administration of insulin. Ill health due to attitudinal derangement may be temporarily corrected by authoritarian advice and logic, but to correct the basic issues, the emotional factors underlying the attitudes will have to be dealt with. There will have to be some sort of corrective emotional experience along with logical explanation if fundamental changes in attitudes are to be accomplished.

If this be true, then the physician will have to give greater scientific place to the art and skill of medicine than has usually been his wont during the recent decades of rapid advance in the physiological and parasitological aspects of disease. The art of using the emotional experience in therapy must be recognized as a part of the science of medicine; the art must, so far as possible, be reduced to principles, and the principles to a useful science which the physician may use with the same pride and satisfaction he now has in the exactness of the hematocrit or the serological tests for syphilis.

It has been one of the most important findings of psychoanalytic research that the emotional experiences necessary to change attitudes cannot or do not take place unilaterally, that in every case the emotional situation necessary for attitude changing involves the physician as well as the patient. The statement of this principle has required some courage in the past, for a profession has been told, and to a surprising extent the telling has been accepted, that it could not deal with human patients without becoming humanly-emotionally-involved. The profession has long recognized the art of medicine; it has more recently realized that this art is not practiced *on* a patient, but *with* a patient, the physician participating in the interaction.

Boiled down to its very essence and applied to the field problem, these concepts have been stated by Ginsberg (1950).

Mental hygiene is concerned with public health programs at every point, since practically all programs have an element of attitude-changing about them. The details of the place of mental hygiene in programs will be discussed more fully in a later section. Suffice it to say here that no person in the health department is free of the necessity to realize that his job has to do with attitudes, his own and those of others. The top administrator will be concerned with attitudes of employees, knowing that the quality of their contacts with the clientele of the department will be affected by them. The clinic physician cannot help but affect attitudes and will need to recognize his own as well as those the patient exhibits if the best promotion of health is to be achieved. The sanitarian will need to recognize that his ability to listen to the explosive protests of the man selling milk without a license is frequently



an unavoidable by-product of the changing of attitude necessary to lead to submission to the regulation. Recognition that the process of attitude-changing which is necessary to lead to a desirable action as a mutual experience, is also a recognition of the all-pervasive character, the "horizontal function," of mental hygiene in the health department.

When it can be granted that attitude changing is not something done *to* people, but rather that it is a mutual experience lived through *with* people, the client gains in stature. He is no longer a body to be managed, but a person with whom an experience is shared. As such, he deserves greater consideration as a person. A two-minute interview with the mother of an infant in child health conference is seen not to be enough; the experience cannot but be incomplete and frustrating for both participants, physician and patient. Authoritarianism with the tuberculosis patient resistant to hospitalization becomes unsatisfactory as a means of management in many cases, not only because it frequently fails, but because the physician or nurse feels he has failed in his part of the process of attitude-changing to lead to the health-promising action. The clinic practices will require more attention to the patients' views, and the time it takes for attitude-changing will be taken into consideration in scheduling and planning. Clinics will be planned with the patients' as well as the physicians' comfort in view, since the process of treatment is not imposed *on*, but rather, worked out *with* the patient. The health educator can hardly be bored with the uninformed question when he catches the scent of the attitudes it reveals and the need to work them through with the group to which he is speaking.

The discussion of technics of mental hygiene has thus far dealt exclusively with the implications of the interpersonal relationships in the development of the personality and the determination of its mental health. There is no intention to neglect the personality-forming forces that lie in the cultural, sociological, economic and other areas. It is probable, however, that these forces are not felt directly until personality has developed considerably, until the child comes into contact with a wider environment than his home and immediate community. It is probable that such forces become directly formative only after the child starts school, and are not very strongly effective until the adolescent period of development when the tendency to make comparisons becomes acute. Prior to this time, and continuing in and beyond it, forces such as poverty, poor housing, low cultural standards in the community, lack of recreational facilities, etc., are felt not directly, but through their effect on the personalities surrounding and guiding the child and from whom he gets his interpretation of the culture and the environment. The child is likely to feel poverty in such ways as the pain in his mother's back which is the result of her being unable to afford a washing machine and which makes the mother very irritable, than in any more direct way. Improper nutrition may result from poverty, but the impact on the child of the situation is more likely to come through the parents' frustration and guilt than from its own realization of lack of money in the family.

There are many aims in mental hygiene which are identical with those for most other diseases. Good housing is as much to be desired as a preventive for mental ill health as it is to prevent tuberculosis. Good nutrition is a preventive for mental illness as it is for pellagra. The interpersonal factor of attitude formation and manipulation has been stressed, however, because it is more specifically related to mental hygiene than these more impersonal forces.

## MENTAL HYGIENE IN PUBLIC HEALTH PROGRAMS

There are few agencies in modern social structure which direct their services to all individuals in the entire population. Two stand out immediately which do, public health departments and public schools. In actual practice, public health programs are, as far as the more personal clinical services are concerned, largely confined to the lower socio-economic levels of the population, though this pattern is changing rapidly as more and more methods for the preservation of health are learned and are recognized as separate from the practice of curative medicine. The health promoting possibilities of the science of nutrition are a case in point; mental hygiene is another.

The argument as to what is treatment and whether it is ever a proper part of public health programs is nowadays largely an academic one. Treatment, it can be argued, is always preventive in nature, preventive of progress of disease, preventive of death, preventive of chronicity and long morbidity. This is largely a specious argument as are most of those so often made in the case. Actually, the questions are usually settled pragmatically. Syphilis treatment became a part of public health programs when it became treatable but the treatment was so long that it required a follow-up system not available to the practitioner and too expensive to be borne by any large segment of the population. Pneumonia in the days of serum treatment became a public health problem for a short period because too few physicians had the necessary technical skill to make a diagnosis of type of organism, and, again, because of the cost of the treatment. When a new treatment was discovered which was less costly and did not require a new, specialized diagnostic skill, pneumonia was returned almost at once to the physician for handling; syphilis treatment appears to be going the same way with the rapid reduction of cost and the greater simplicity of treatment procedure, only the epidemiology being retained as the health department function. Full medical care for the indigent has been a part of public health practice since the origin of public health in ancient times. It is perhaps a reasonable pragmatic conclusion that when any medical problem is too expensive or requires special technics not available to the general practitioner or which the physician does not care to handle, then public health will become responsible in that area. It is on this sort of pragmatic basis that public health programs are usually constructed, and it is from this viewpoint that the place of mental hygiene in representative programs will be discussed.

**Hereditary Factors.** The promotion of health in any individual begins with the moment of conception. Mental hygiene in the prenatal clinic attempts to see to it that the family into which a child is born is as healthful a place as possible for its optimum development. That there are vast differences in the quality of the new individual that comes into being at the moment of conception is quite obvious. Variation runs the full gamut from the extraordinary potential for genius in all lines of human endeavor to the almost complete absence of potentialities in any direction other than ability to maintain a purely animal existence; in the most unsuccessful conceptions even this potentiality is exhausted before the period of gestation is over and abortion or miscarriage occurs. This variation may be due to one of two factors: first, a predictable one based on characteristics of the histories of the father and



mother, second, an "accident" occurring in the complicated cellular mechanics of the merging of the chromosomes of egg and sperm.

It is a curious fact in the history of medicine that heredity is likely to be used to explain the presence of incurable disease, whereas the diseases which can be successfully treated are rarely regarded as hereditary. Phthisis was thought to be hereditary until the etiological agents became known, and racial (hereditary) susceptibility was long used to explain the differences in death rates in white and colored people. As the multiple etiology, the host factor, in the etiology of the disease gained recognition as well as the bacterial agent, the racial difference was recognized as not solely, at least, due to hereditary differences between Negro and white, but due to differences in socio-economic factors and in other conditions of living. The same depreciation of the importance of hereditary factors has taken place in diabetes and, perhaps, also in cancer.

The complexities of the etiology of many mental diseases are still not by any means completely worked out, and definitive and directly specific treatment methods are unknown. For this reason, perhaps, heredity is seized upon as a very important factor in the etiology of them. It is quite possible that eventually it may be found that some of the conditions now ascribed to hereditary causes will eventually be proved to be of other origin. In any case, the easy blaming of hereditary etiology is frequently a deterrent to the research necessary to prove hereditary origin, as well as to continuing therapeutic efforts. Sterilization and birth control, as mental hygiene measures for the prevention of the birth of children in whom mental deficiency of severe degree and certain neurological diseases can be definitely predicted, is certainly defensible. Perhaps equally often, these procedures may be defended not on the ground of heredity but on the ground that a given set of parents is not capable of rearing children properly and will produce exaggerated susceptibility to disease in them. It is rare that the local health department can be active in the area of mental hygiene that has to do with the prevention of births, even though the problem is clearly recognized, because of the complications involved with some religious sects which treat this area of biology as a moral rather than a scientific issue. With increasing population pressures over the world, it is possible that the selective planning of the number and spacing of births may eventually be a public health issue on other grounds than those of hereditary disease.

**Prenatal Clinics.** The health of the fetus can be interfered with by a list of factors that is becoming longer as knowledge is gained. The effect on the fetus of rubella infection in the mother, particularly if the disease occurs in the early months of the pregnancy, is one of the most startling of these factors. [It should be a part of the mental hygiene program of every health department to have a plan for such protection of the pregnant woman as is possible ready to put into effect when an epidemic of rubella should appear. The newspaper releases, the radio spots, the movie trailers should be ready for the emergency so that as far as we are able cataracts, mental deficiency, and congenital malformations of the heart in the unborn child may be prevented (Ober and others, 1947). There is, of course, also work to be done in research to find ways of immunizing females to the disease before the childbearing period. This problem has many points of similarity with that of the treatment of syphilis in the pregnant woman.]

Another factor influencing the health of the unborn child is nutrition, which

discussed elsewhere in this volume. Certain drugs are known to affect the unborn infant; perhaps the most important are sedatives, which, when given in too large doses to the mother during labor, reduce the capacity of the newborn to obtain sufficient oxygen as soon as it is born, thus subjecting the nervous system, which is extremely sensitive to anoxia, to the risk of damage. There are many other factors which may be capable of damaging the unborn infant, such as toxemia of pregnancy and metabolic diseases in the mother.

For the most part, the factors dealt with thus far are at the level of the organic development of the infant; there are other factors also to be considered during the prenatal period which have to do with the emotional setting in which the child is to mature.

The most obvious of these has to do with the attitude of the prospective parents toward the child. The foibles and fears of the pregnant woman are well recognized as important elements of her life during pregnancy (Blass, 1950). Many have felt that some, at least, of the usual symptoms occurring during pregnancy are related to the mother's attitude toward the pregnancy. Research indicates that the emotionally well-adjusted mother delivers with fewer complications than the emotionally unhealthy mother (Wooten, 1950). Psychotherapeutic relief of hyperemesis is an acceptable method of treatment by most obstetricians, even though too often it is the crude psychotherapy of a very dull needle used in intravenous feeding. It is believed by some that pre-eclampsia occurs more frequently in pregnant women under severe emotional stress than in those not so burdened, though this remains to be statistically demonstrated.

The common emotional stresses occurring in pregnancy appear to lie in three general areas. First, the prospective mother shows concern about her capacity for bearing and mothering a child. Second, she shows increased concern about sexual anatomy and physiology and about the effect of childbirth upon her body and her personality. Third, there appears a concern about her relation to her husband during the pregnancy and the period to follow it. In line with the earlier discussion of basic techniques in mental hygiene, it will be recognized that these stresses may be dealt with by educational efforts taking place in a situation in which the emotional component is clearly recognized and used in a relationship with the patient. The successful use of mothers' classes in prenatal clinics indicates that the fears concerning the process of childbirth itself are readily dispersed by frank discussion and by teaching the physiological anatomy of pregnancy and delivery. This is largely the basis of the "natural childbirth" movement of Read (1944) and Jackson (1948). Even without the open recognition of the deeper basis of fears associated with pregnancy having to do with the almost universal association of a feeling of guilt with sexual activity, such methods, whether carried out with individuals or with groups, relieve many of the anxieties. Classes in baby care similarly tend to relieve the fears of the normal woman that she does not have the capacity to be a "good" mother.

It is apparently a part of the normal psychology of pregnancy, at least in our culture, that the woman should become more self-centered than is her usual wont. Her husband is less important to her, her concern is upon herself and her infant. There is perhaps some guilt associated with this which makes itself apparent as a fear that her husband will desert her, something that occurs often enough, especially in the lower socio-economic groups, to justify the concern. This is a matter that can



be discussed both in interviews with the mother, and with the father, who has been too much neglected in the prenatal clinics.

Not infrequently, pregnancies are not welcomed, sometimes for exquisitely realistic reasons having to do with inability to feed and clothe another child. In other cases, the pregnancy may be rejected because it is felt to be a threat to the beauty of the mother, and of the freedom of the parental couple. It has been observed that feelings of rejection normally become less as a pregnancy progresses; the girl who never even wants to see her baby in the first trimester is waiting happily for its appearance by the time delivery comes or as soon as delivery is over (Wootten, 1950); Klein and others, 1950). This phenomenon occurs frequently in pregnancy; recognition of it may relieve the physician and the nurse who worry about what is to become of the child early in the pregnancy only to find their worries useless in the majority of cases because of the change of maternal attitude. Acceptance can undoubtedly be favored through interview and group teaching during pregnancy.

A topic of importance in the prenatal care of the multiparous patient, particularly of the mother in her second pregnancy, is the introduction of the new baby into the life of the child or children already in the family. Children tend to want the exclusive attention of their parents, particularly their mothers, and they resent the intrusion of the helpless infant that so successfully gets first attention. This problem is the more acute because the succeeding child appears frequently when the previous one is in the period of negativism to be discussed later. This problem is most suitable to be discussed in the prenatal clinics. The sex education of the children already in the home is also likely to be a matter of question by the mother during her pregnancy.

The introduction of the issue of sibling rivalry as a topic to be discussed even before the rival appears on the scene is an example of a principle of mental hygiene that deserves discussion as a general technic. A situation which is known to give rise to emotional conflict in a significant percentage of families is dealt with in discussion before the situation actually arises. The aim is to lessen the emotional impact of the situation and, consequently, its potential as a source of conflict. To use a humble analogy, if one is watching an open door and sees it begin to close as a result of a draught, sees it speed up as it nears being closed, he is not likely to jump when the slam, seen to be inevitable as soon as the door began closing, actually comes. If, however, the door is at one's back, and the stages of its closing are not seen before-hand, the slam comes as a sudden shock and results in an involuntary, violent "jump." Sibling rivalry can be a great shock if one does not know that, at least in our competitive culture, it is almost inevitable. The shock of its appearance may lead to ill-advised handling such as punishment, shaming, and withdrawal of affection from the child. It should be expected to occur in some degree and appreciated as a justifiable defensive reaction of a child who sees affectional sustenance being withdrawn from him by an intruder in the family circle. When the parents understand the needs of the older child, provide the affection he is striving for, and give him an opportunity to participate in the care and affection given the new baby, healthy responses are encouraged. This concept of "anticipatory guidance" (Levy, 1946) will appear again and again as a basic technic in mental hygiene in public health, from the situation in prenatal care, to the preparation for retirement in old age.

**Prematurity.** The great increase of public health programs to preserve the life of premature infants has raised some new problems in mental hygiene. In the first place there is the fact that the birth and the child are not "normal," a situation that makes the parents feel different from others. There is also the common fear that the premature infant will not develop properly, a fear not entirely without foundation since blindness due to retrolental fibroplasia does occur. Cerebral injury during the birth process is a greater risk for these children than for the more mature infant at term because of underdevelopment of the protective tissues about the brain. The prevention of prematurity is good mental hygiene in the light of these facts.

The "abnormal" condition of the child and the birth may lead to feelings of isolation and self-blame, frequently associated with feelings of guilt and of unworthiness in that the parents have failed to produce a normal child in a normal way. It is easy for this self-blame to be projected upon the child so that it is somehow disliked for having inflicted the anxiety and, not infrequently, shame on the parents. There may be disappointed grandparents and other relatives who do not hesitate to blame one or the other marital partners for the mishap, thus throwing additional strain on the husband-wife relationship. There is also the very real anxiety concerning the viability of the child which is a stress the medical attendants may share with, but too frequently falsely deny to, the parents. These factors all add up to explain why telephone calls are so frequent to the premature ward; they also indicate the need to treat the frequently bothersome caller sympathetically and with understanding.

The fact that the precarious condition of the premature infant requires hospital care interrupts the mother's taking over the care of the child immediately after its birth. Instead she must put off the practice of motherhood for weeks or months, until the child is ready to come home. The expected sequence of pregnancy-delivery-care of the infant, looked forward to for months, does not come off on schedule; adjustments have to be made. Babies are often referred to colloquially as "little strangers"; a period of hospitalization for the child tends to accentuate its strangeness when it does come home. There are no data to support the supposition but it has been suggested that more premature babies are abandoned by their parents than is the case with term babies. If true, such a fact might have many explanations, but an important one might be the delay which makes possible the setting up of living habits which do not for weeks or months after delivery include the baby, with resultant failure to develop the sacrificial quality of love which appears when the infant needs immediate care.

As will be the case throughout this discussion of the place of mental hygiene in public health programs, these do not exhaust the factors involved. It is merely an attempt to indicate the types of feelings, some of which are emotional stresses of some magnitude, which demand recognition as significant features to be considered and dealt with on a premature service. In general, they are factors of emotional stress and must be dealt with through the technic of interpersonal emotional exchange, through sensitive interviewing or group technics.

**The Well-Baby Clinic.** (Child Health Conference, Baby-Keep-Well Clinics, etc.) In general, the work of the well-baby clinics includes the period of life from birth until the child begins to attend school. These five or six years are usually divided into two periods: that from birth until about two, designated infancy, and that from three until five, called the preschool period. Physiologically, this is a period



of momentous changes, perhaps best illustrated by the fact that the newborn infant grows about eight times as fast as the child at three. Nutritionally, feeding changes from the exclusively liquid diet of the infant to the pattern of eating common to the group in which the child is nurtured. Culturally, the child changes from the completely dependent infant to the relatively self-reliant school child, and from the accepting infant to the individual willing to defend his place in his culture. Neurologically, the child changes from one who can make only random movements to one who can plan and act in a relatively accurate way, from one with no sphincter control to one who can adjust elimination to some extent to the rules of the people with whom he lives. It is not remarkable that a period showing such enormous growth should be considered important in mental health. Attitudes which affect the essential soundness or weakness of personality structure are forming with as great rapidity as are myelin, bone, and muscle, perhaps with even greater rapidity.

Once the basic physiological demands are met, the primary ingredient in the life of the child which is necessary for optimum growth and development is an appreciative, accepting and loving attitude on the part of the parents. Such an attitude has already been fostered in the prenatal clinic through discussions of attitudes with the parents and helping the parents reach this emotional state. Anxieties have been relieved so far as possible, resentments toward the infant have been frankly recognized in so far as possible, and hopefully, the home is ready to receive the baby.

The initial experience with the child is rarely completely under the control of the health department but is in the hands of the obstetrician or midwife, or a hospital. Nevertheless, rooming-in and breast feeding will be discussed because of their mental health significance according to current thought.

The new baby has since the earliest times been the companion of its mother. Since the discovery of asepsis, however, this time-honored relationship has been interfered with, and the child is relegated to a nursery, the mother seeing it only at feeding time, if then. While this is probably less of a problem than it was a few years ago when obstetrical hospitalizations were 10 to 14 days long, it is nevertheless a matter which is at present receiving a good deal of attention as a factor in the mental health of the mother, and through her, of her infant (Maloney and others, 1946). It is known that mothers have considerable anxiety about their infants when they are separated from them and that they are more comfortable when the infant is at hand, can be seen, and can be attended to when it needs care. Mothers are fully aware that hospital nurseries are usually understaffed and that infants are allowed to cry unattended in them longer than would be the case if the child had its mother's care (Aldrich and others, 1945). Crying in the newborn infant is an indication that it is not under optimal conditions for its growth and development; crying in nurseries can be greatly reduced by increasing the amount of nursing care per infant, and can be still further reduced by placing the child where its mother, with such help as may be needed, can attend to its needs when they are demonstrated by crying. Rooming-in of the child with its mother makes this possible. Rooming-in can provide relief from some of the mother's anxieties about her baby and can actually afford more optimal conditions for the child than can be given in the hospital nursery.

The period of rooming-in can also be used to allay some of the anxiety of the mother about her competence as a mother. She can learn under experienced guidance

ance the hows and whys of infant care over some days, not through the seeing of a single bath performed by someone else as was hospital practice until recently. Another factor in the mental health situation is related to the modern movement toward early ambulation. It appears clinically that there are fewer marked depressive reactions in women returning home after childbirth since hospitalizations have been shortened and it is the impression of workers in this field that this is even more the case when the mother has charge of the infant in the hospital.

In most rooming-in programs, the father is able to become acquainted with his infant directly and not through plate glass. This cements the family group earlier than is the case if father learns only of the difficulties of infant care after the child is at home. Rooming-in probably fosters breast feeding, though this is difficult to demonstrate since the programs now in operation tend to select mothers for this type of care partly because they wish to nurse their children.

Quite aside from the advantages of breast feeding from a narrow organic viewpoint and the convenience of it, there appear to be advantages to the mental health of the child and the mother. In the first place, the infant cannot be breast fed unless it is held closely to the mother in a cuddling manner; at least the *forms* of giving affection and security are insured.

The infant will cry when support is suddenly withdrawn; from this the assumption may be made that the optimum conditions for growth and development include such pleasantly firm cuddling as is unavoidable in the nursing position. The establishment of attitudes toward food and eating have their first opportunity to develop when feeding first takes place. While it is true that the whole experience is lost in the infantile amnesia, it is not unlikely that attitudes which so often cannot be explained on the basis of remembered experiences are actually preserved from these original feeding experiences. Until quite recently there has been considerable fear of "spoiling" infants by holding them during artificial feeding. We have seen cases in which the mother denied herself the satisfaction of holding the child during bottle feeding because of this fear, quite overlooking the fact that were the child breast fed she would perforce have to hold him. These mothers frequently are very grateful when encouraged to enjoy cuddling the child during feeding.

The care of the infant is a difficult, time-consuming, and tiring task which would probably be unbearable except for the satisfactions that accrue from it. Unless the mother can feel the deep thrill of her love for and joy in serving her infant, she is likely to resent its intrusion upon her. A part of the satisfaction arises out of cultural and developmental factors. She is proud before the community of the accomplishment of childbearing. She may see in the child a sort of fulfillment of her destiny, a recurrence of a feeling commonly appearing at the onset of menstruation. The infant is also a product of her sexual life, and where this sphere is satisfying, the care of the child has a certain sexual significance, giving satisfaction on a sensual-emotional level. Breast feeding binds itself to all three of these areas of satisfaction and thus contributes to the mental health of the well-adjusted mother. It is hardly necessary to add that there are mothers whose cultural and sensual-emotional lives are so restricted and barren that they cannot accept the satisfaction of breast feeding; when such situations are severe, the infant may be protected from the mother who is made tense and irritable because of this intrusion on her privacy of body and be better served by artificial feeding (Fries, 1937). It is perhaps worth while to



mention that, while perhaps above 90 per cent of women could breast feed if they chose, there are those who cannot; these need to be protected from feelings of guilt about their failure.

Attitudes toward feeding are set up not only through contacts with the mother, but also through the timing of feeding in relation to hunger. The theory that the infant is a metabolizing machine running on schedule, which grew up during the highly mechanistic period of medical practice and psychological research just past, led to the establishment of fixed interval feeding schedules unrelated to the occurrence of hunger in the individual child. To be sure, the interval was determined basically from the average time between feedings demanded by infants, but it disregarded two factors: first, that there is wide variation in infants, and second, that patterns vary at varying ages. Gesell (1945) has shown that hunger occurs in a rather random pattern for the first few weeks of life, later settling down into a reasonably regular one. In the individual infant, sticking to an imposed clock schedule results either in frustrating waits or feeding when not hungry, thus serving to contaminate the feeding activity with attitudes deriving from anger at frustration or from ennui. It is to avoid this association of negative attitudes with feeding that has given rise to the concept of self-scheduling, which means feeding the child when it is hungry. It is quite clear that the public at large never accepted rigidly scheduled feeding; recently in a well-baby clinic several mothers admitted in interviews that they fed their infants when they were hungry, but quickly added that they didn't tell their pediatricians since the latter didn't approve!

The introduction of solid food is an event of some significance, again because attitudes in process of formation are associated with it. Solid food is a new sensual experience and requires new muscle movements of face, tongue and pharynx for its management. Furthermore, it runs counter to an important protective reflex present in all healthy infants, the reaction of extrusion which takes place when objects get into the buccal cavity. These and other factors frequently make the child awkward in handling solid foods at first, and if feeding is insisted upon, make it angry so that as much willful resistance as the child is capable of is added to the basic lack of skill. The mother's frustration, if there has not been anticipatory guidance on the point, is likely to be reflected in the infant's reactions, leading to loss of satisfaction on the part of both mother and child. The primary issue is the preservation of appreciation of and satisfaction in the infant by the parents, particularly in this early period by the mother.

A factor in this promotion of appreciation will be satisfaction gained through noticing the development of the child in many spheres such as emotional reactivity, language, locomotion, sensory appreciation of the world about him, and others. Instruction in observing these activities is a mental hygiene function of the well-baby clinic. For the most part, in the past these developmental factors have been used primarily for diagnosis of retarded or accelerated development. While this is a legitimate medical use of such data, it is hardly justifiable for use by parents except in special cases. The competitive character of our culture presses strongly to make all parents strive to make their children better than others. Developmental averages are prostituted to this end, frequently interfering with the satisfaction of the parent in the child. It is justifiable to demonstrate the unfolding growth of a particular

child, stressing its individuality rather than its place in some percentile scale of development.

Locomotor development poses some particular problems, for as soon as a child learns to walk it also learns to climb and explore. This is again an opportunity for anticipatory guidance. Appreciation of the child's development will not be interfered with by too much broken bric-a-brac since such articles have been put out of reach in anticipation of the climbing.

Immunizations have received a good deal of attention as mental hygiene factors (Huschka, 1944) since children frequently respond violently to them. Usually, violent reactions are traced to the parents, the parent being accused of frightening the child and of being frightened themselves so that the child mimics their attitudes. (Later, after speech is established, the doctor may be used as a threat.) Physicians are accused of falsely acting as though there were to be no pain and then suddenly giving a good deal of pain. In the prelanguage period of development it is possible that attitudes are established toward necessary medical procedures which may persist even though specific memory is not present. There is some evidence that medical procedures completed before the age of eight months are not remembered to affect future actions; on this basis it would appear wise to complete as many such procedures before this age as possible (Levy, 1950). A discussion of the impending immunization procedures with the mother before they are to take place, perhaps allowing her to observe the procedure in children other than her own, may help to relieve her anxiety and to allow her to be more helpful to the infant when its turn comes. The physician's attitude will be sympathetic, but matter-of-factly accepting that some helpful medical procedures are unavoidably painful and must be endured by both mother and child. This is undoubtedly more successful than insincere declaration that "it won't hurt a bit" which the doctor's conscience usually forces him to shade with "just a little needle prick."

Associated with the rapid decrease in rate of growth from birth to the middle of the preschool period, and with the change in types of food eaten, there is usually a marked decrease in appetite. It has been amply demonstrated (Davis, 1928) that the child allowed to eat only as much as it wants of a variety of foodstuffs will eat a diet which results in satisfactory growth and development. The difficulty is that the diet selected by the child is likely not to be one fitting the habits of the family in which it lives and, also, that the family is likely to be dissatisfied with the amount the child eats and the time taken to eat it, as well as the way the food is eaten.\* A discussion of the difficult mechanism of handling eating utensils for an organism just learning the extent of its own body, of the balance of muscles necessary for smooth movement, may avoid the irritation that arrives when expectations exceed possible performance, thus protecting the child-parent relationship.

The issue of toilet training brings out very similar problems. It is probable that sensitivity to the fullness of the bladder cannot reach consciousness until well after the child is walking and that about the same time relative control of the sphincters becomes possible for the child. Because of this, there would appear to be little gained from trying to "train" the child earlier, though on an unconscious, conditional

\* The feeding sequence in the film "Preface to a Life" (Mental Health Film Board, Inc.) is sometimes criticized as overdrawn. Clinical experience will, however, show it to be a reasonably accurate representation of the situation in many American middle-class homes.



reflex basis, it is probably possible to achieve bowel movement and even urinary voiding at a convenient time and place. This is aided by the fact that mothers become quite adept at recognizing the early signs of voiding reflexes and "catch" the movement, generously giving the child credit for his interpretation of its activity. Too frequently it is not recognized that the child is unable to exercise any conscious control, however, and failure is likely to be blamed on the child, thus making him an undeserving culprit and putting stress on the home relationships.

Emotional control is, in a somewhat similar way, likely to be expected before the child is able to exercise it. After the child is walking well and begins to have some language, it also begins to develop the notion that it is an individual in its own right and there begins the first struggle for independence from the parent. This is a struggle that will be repeated in adolescence when it will be associated with a great deal of anxiety because of the difficulty of determining just how much independence the child actually needs for his optimum growth and development. At two or three, however, assertion of independence in the period of negativism appears a little ludicrous, and the parent, unless pushed to anger by embarrassment before friends, is likely to look upon the incessant "I won't," "No, No," and "I don't want to," with tolerant amusement. When insistence on action leads to the violent temper tantrum the parent is likely to lose patience completely and fall into punishing procedures almost as preposterous as the child's resistance. Such reactions which leave both child and parent exhausted and frustrated and damage the relation between the two are, to some extent, forestalled if the parent has learned before the first reaction of negativism to expect it and to see it in perspective as the budding maturation of a new and individual person.

Similar reasoning and experience shows its pertinence (Cooper, 1948) may be brought to bear on most of the problems of the preschool child's life. The qualities of possessiveness and sharing, of being able to dress, of delaying washing before meals, of hitting other children, of denying love for the parent, etc., may be handled in the well-baby clinic by foreseeing their probable occurrence in a child and giving the parents a basis for appreciating them as evidence of growth and development, rather than evidence of moral depravity based on devilish disregard of the Fourth Commandment. Preparation may be done individually or in groups in which the more experienced parents can share their experience with the parents going through the difficulties for the first time.

The central theme of mental hygiene as it appears throughout the program of the health department, but particularly in child health programs, is that the physical and emotional development of the child should be appreciated and furthered rather than thwarted and restricted; that development of the person be guided under the attitude that Senn has described as "permissive with limits" rather than confined to some preconceived, rigid path which could not be adaptable to the individual child in question in the light of the known wide variations in children's personalities and rates of development. The aim of mental hygiene is to see to it that each person develops its individual potentialities as fully as possible so that the resulting adult will present maximal health and strength of personality. This is believed to be the best possible basis for the prevention of mental illness as well as all other types of disease in which there is any personality involvement. Furthermore, such a concept is the only one tenable in a democratic society which has as its aim the development

of the individual to his highest capacity in order that the society itself may be borne on the shoulders of strong, healthy-minded individual citizens.

The concepts presented thus far have little apparent relation to the rather complicated psychoanalytic picture of family relationships typified in the Oedipus theory. Such difficult and often not too well substantiated theories are probably not suitable for use by the health officer or nurse. While all the concepts thus far dealt with can be taught only in the setting of warm interpersonal relationship, it is in all probability only in a setting of a much deeper "transference" type of relationship that these drives can be dealt with because they involve such basic emotional values of the parent and child. Deep rejection, serious jealousy of the child or of its relationship with one parent by the other, persistent and exaggerated behavior difficulties which are seen to be symptomatic of the preceding types of parental reactions, are cases for referral to the psychiatrist or child guidance clinic. These more pathological reactions can be spotted early, though too often they are referred late when the reactions are not only present but fixed by habituation.

As the child reaches five or six, both he and the parent will be facing the fact that it will shortly be spending five or six hours a day out of the home. The child, particularly if it has older brothers and sisters in school, will not infrequently hurt its parents' feelings by its obvious wish to get into school and away from home. The mother who has had to live through the difficult stresses of the preschool negativism for more hours a day than the father, may also look forward to the child's being away, though she may feel rather guilty about her conscious partial rejection.

Even though the child who has been allowed to grow into an individual usually looks forward to going to school and is familiar with much of school routine through conversation about the house, it is still likely to feel awed by the enormity of the new adventure—the big buildings, the strange, separate-sex toilets, eating away from home, frequently a bus ride with strangers, a new adult to deal with. Anticipating and recognizing these reactions is the aim of the "preschool roundup," a gathering of children to start school in the fall, the spring before, and their mothers. Mother and child meet the teacher, and learn about the building and become desensitized to it. Discussion of the mother's attitude toward starting a child in school has not been very highly developed, though in many programs, there is obvious tacit recognition of its importance. The physical examination and immunizations that are the usual reasons given for the preschool roundup tend to overlook these basic mental hygiene gains, a more conscious development of them would probably contribute to the family's interest and cooperation in the roundup. It is hardly necessary to point out that the issues of the preschool roundup will have been faced earlier by the mother who has sent her child to a nursery school or day-care center.

These latter two institutions are of real importance to the health department. Usually it is responsible at least for the licensing of the building and grounds to be used by the school or center, and not infrequently it is also responsible for health inspections of the children, at least for the nonproprietary schools and centers. In cooperation with the department of education there is not infrequently some control over types of educational program, selection of equipment, etc., and this trend is likely to be extended in the future as nursery schools more frequently are incorporated into systems of public education. Ideally, the day-care center and the nursery school should have very similar programs, though the former usually cares



for the child for a longer period of time, the mother's working day. Too frequently, for economic reasons mainly, the day-care center will be manned by a less well trained staff and have poorer equipment and housing. The aim of the nursery school is to provide optimum stimulation for the growth of the child from the ages two or three until five. The small families now the fashion in many groups in our culture do not offer sufficient contact with contemporaries during the period when basic attitudes toward sharing, taking turns, respect for the opinions of others, etc., are laid down. Furthermore, many toys that are advantageous for the development of muscles and coordination are too bulky and too expensive for the individual family to own; they can be provided for groups. In addition to these advantages for the child, the nursery school offers an excellent opportunity for the teaching of parent-craft. This is an important part of the work of the better nursery schools. The alert health officer will find the trained nursery school teacher an excellent resource for staff education, particularly of nurses and physicians working in the well-child conference. Though not designed as a treatment agency, the nursery school may offer therapeutic possibilities for particularly severe feeding and relationship problems in selected cases (Blatz and others, 1935).

**School Health Programs.** Throughout the first years of its life the child has spent most of its time in the family circle and has been measured by standards that vary widely. When he starts school he is measured against a large group of his contemporaries, and by methods far more standardized than any used in homes. He is measured against tasks not heretofore encountered and tasks designed to fit the abilities of the majority of the children, though not all. Furthermore, he is measured by persons not related to him and not responsible for his whole life; the teacher may not be objective in judgment, but the prejudices introduced in judging the child are not the same as those of parents. It is perhaps for these and other reasons that most new cases arriving at child psychiatric clinics are older than school starting age, though the problems needing treatment are found to be of several years duration when investigated. Careful work in well-baby clinics in the future will, hopefully, make the sudden increase in recognized problems as the beginning of school life arrives less acute.

The principal problem of school systems is the maintaining of the concept that each child is an individual with unique experiences even though millions of children must be educated. The mental hygiene opportunities in the school are two: first, to safeguard the rights of the child who is "different" and does not fit the educational "production line," however much understanding of variability and appreciation of it the teacher may have, and this understanding and appreciation are major concerns of teacher education. The second opportunity for mental hygiene in the schools is the inclusion in the life of the child of experiences and knowledge that will lead to strong personality structure. Of the two tasks, the first is, at the present time, by far the more easily defined and executed. The second is very much still a matter of experiment and, to be sure, of controversy.

Although it has by no means been accomplished, it is logical to assume that psychiatric diagnosis at least, and perhaps psychiatric treatment, should be a part of the school health program. The school health program, as soon as it leaves the very narrow standard of recurrent, cursory physical examinations for each child and begins to look more widely into the child's life through the nurse-teacher con-

ference and the inclusion of the parent in the physical examination and history taking, inevitably finds mental health problems. For example, in a suburban school it was found that no less than 80 per cent of first graders were considered to be feeding problems by their parents. It is very well known that many illnesses show themselves by changes in behavior before physical signs appear; the teacher frequently sees these phenomena first and when they are recalled to her through the teacher-nurse conference they can be studied. Thus, the school physician will have many more difficult diagnostic problems to solve, and he will find that a good many of them will be behavior difficulties of emotional origin.

Having made the diagnosis, there will immediately arise the problem of treatment. With the improvement of psychiatric training in medical schools and in hospital residencies, both general and pediatric, more and more of this treatment will come within the ability of the nonspecialized physician. We may even hope that with increased skill, the school physician will find sufficient confidence in dealing with mild psychiatric problems that he will not so constantly have to defend himself against accepting any responsibility for them by crying that he has not sufficient time to treat. There will be found to be many cases which require only short treatment to give very rewarding improvement.

There will, however, be a remainder of cases in which more extensive treatment is needed, both of parents and of the child. There is almost nowhere in the world where the cry does not arise that there are insufficient treatment facilities and this is likely to continue for a long time yet to come due to shortages of psychiatric and auxiliary treatment personnel, and also to the fact that treatment remains a slow and therefore expensive procedure when the illness is severe. The advantages of early treatment, before school age is reached, have already been mentioned, and there is no dearth of patients needing treatment beyond school age. For these reasons, it is believed that clinics to treat cases exclusively recognized in the school, are probably not ideally to be made a part of school health programs. Clinics are probably best established independent of the school and free to accept cases from other sources as well. In some cases, they may receive support from the educational system proportionate to the part of the case load originating in the schools. A subtle advantage of the separation of the treatment agency from the school is that medical treatment, particularly psychiatric treatment, is not best performed under authoritarian powers, and, however much the school may seek to keep its standards flexible and pupil centered, the fact remains that there is the ultimate legal authority that children shall go to school, which can hardly help but influence the clinic atmosphere in the minds of the parents and children, if not in the staff itself. On the other hand, it can be easily demonstrated that a clinic under school auspices generally makes more pertinent and easily followed recommendations to the teacher and principal for treatment of children in the school system. It must also be noted that what is probably the largest single organization of child psychiatric clinics in the world is that operated in the New York City schools, and operated rather independently of the school health program. While no objective measure of its success is available, its survival over many years in a budget with strained resources may be interpreted as indicative that it has been successful.

It is probable that almost 1 per cent of all school children need psychiatric treatment because of relatively severe symptoms; perhaps 10 to 20 per cent will



require careful diagnostic survey and treatment of lesser symptoms at some time during their school careers.

Aside from the usual symptomatology of childhood neurotic and conduct disorders, two other issues need to be singled out for special attention: these are the reading and speech disorders, and mental defect. In both cases, diagnosis is usually the function of the psychiatric team of psychiatrist, psychologist and social worker, but in both also, treatment and management are likely to be in the hands of specialized teachers who have the advantages of psychiatric understanding of the child in the therapeutic and teaching endeavor. With speech and reading disabilities, improvement through special teaching methods, combined when necessary with psychiatric treatment, may be expected to result in real improvement in symptoms.

With mental deficiency, improvement in capacity is not to be expected; the goal is rather to make maximum use of the abilities that are present and avoid stresses that make for conduct disorder and other forms of poor mental health. To accomplish this, mental deficiency will need to be diagnosed early during the preschool period for several reasons. In the first place, it is a matter of anticipatory guidance for the parents to make sure that they do not expect too rapid development of the child and that they obtain maximal satisfaction from the advances that are made. Second, the mentally deficient child requires care in the "dosage" of stimulation it receives so that it will not be inundated by massive doses that it cannot use profitably. The stimulation must be adjusted to promote maximal development within the range of the child's capacity. Obviously, planning for the mentally deficient child's schooling will also depend upon early diagnosis; the conclusion that the child cannot handle ordinary classroom work can and should be made before long series of frustrating failures have added behavior disorder to what might have been a healthy though intellectually limited personality.

The second aim of mental hygiene in the schools is that of helping each child gain the strongest personality structure possible for it. This is the broad aim of all education, educational theory having gone far beyond the more narrow ideal of simply teaching a child certain facts and methods, however much this older ideal is still seen in actual practice. The newer ideal in education means that in the education of the child the facts of actual living will have to be dealt with as well as the three R's and their elaborations. The problems presented are by no means easy to solve.

Very broadly they are attacked by two major methods: first, the selection of teachers whose sound mental health will serve as an example and set the ideals of the child; second, by training these teachers to have an understanding of the emotional and developmental life of the child so that she can lead it toward the soundest development. The methods by which these tasks are to be accomplished are by no means fully known or standardized (Prescott, 1938; Ryan, 1938; Pyle, 1939).

Certain specific schemes have been developed for promoting mental health which must be mentioned briefly since they are resources to which the school health officer may turn. The first of these is counselling. Begun as vocational counselling for adolescents about to leave school, the system has spread to include persons specially trained for dealing with individuals even at the elementary grade level. The visiting teacher system has developed to make personnel available for attitude-changing through their education and experience in social work. The truant officer has changed

from an attendance enforcement officer to a person who attempts to discover and change those attitudes which make school attendance difficult for the child.

The idea that there are certain generalizations about emotional life than can be taught and certain experiences which are helpful to any child has been incorporated in teaching to some degree. Homemaking courses for both boys and girls attempt to teach principles of family living as well as methods of budgeting, how to clean a house, and how to bathe a baby. Marriage courses, begun in colleges where they were found to be highly successful when conducted in an informal, frank and friendly manner, have begun to appear in some senior high schools. Vocational training has begun to consider not only technics of handling materials and machines, but also how to get along with fellow workmen and the boss.

The human relations class (Bullis and O'Malley, 1947, 1948) is a specially arranged series involving discussions of emotionally charged situations with which the child can identify and yet see objectively enough to make a reasonable analysis of them. It offers opportunity for the child to set attitudes toward similar situations that may arise for him in the future. He may also get the habit of understanding and being tolerant of views divergent from his own, and can come to the realization that emotional isolation is largely a matter of not knowing how other people feel rather than that they do not have feelings similar to those troubling the individual himself. There are other schemes in which the general idea that sharing emotional experiences is helpful is worked out in classroom procedure specifically set aside for it.

A second method with the same aim is the incorporation of living emotional material in classroom material (Ojemann, 1946). Although there are many other levels at which this may be done, a convenient example is the study of Shakespeare's plays. Lear and Polonius are examples of old men—they could be discussed in terms of attitudes toward older people in the population. Othello's paranoid thinking and feeling can be the basis for a discussion of jealousy and its effects on family life. The passion of Romeo and Juliet is a topic difficult to deal with but very real to adolescents and very near to experiences that may be deeply disturbing; perhaps they would be less so if completely discussed. Racial prejudice is very much available for discussion in Shylock, the rights of women in Portia. Examples are legion and need to be elaborated no further, nor is it necessary to indicate that if such discussions are to be held, the teacher must be prepared for them. It is not unlikely that the teacher will need the help of the nurse and physician, perhaps the psychiatrist occasionally, in such ventures.

Sex education is a special problem of teaching that is frequently referred to both public and psychiatric personnel. While still a very controversial issue, there appears to be a growing sentiment that the school shall have some responsibility in sex education, either directly, by teaching the child the biology of sex and attitudes toward its functioning, or indirectly, by teaching parents and thus making the material available to the child. There would appear no good reason why the anatomy and physiology of the reproductive system in the human should not be taught as a set of facts on the same level of importance as the anatomy and physiology of the gastro-intestinal tract. The difficulty is, of course, in the area of emotion and attitudes; perhaps the basic difficulty is that most teachers, indeed most parents, are so unused to facing issues in this field directly that they are totally unprepared to face them with children. The motion picture films in the field of sex education



(National Institute of Mental Health) are very helpful in preparing adults for this task, and when these are prepared, for beginning discussions with children. The emotional concerns associated with the pubertal growth spurt offer a field in which knowledge of the developmental pattern can relieve the anxiety and feeling of isolation normally aroused in the child who is much larger or much smaller than his contemporaries at a particular time.

The mental hygiene aspects of the school health program comprise two problems: first, that of the "case" and its treatment; second, the teaching of as yet not clearly defined mental health principles to all children and their teachers. The technics for the former, although subject to improvement, particularly in attaining less costly and time-consuming treatment methods, are well known. Whether the therapeutic service should be a part of the school itself or a community service used by the school once diagnosis is made is a moot point, in general, best resolved in favor of the latter type of organization. Mental health education consists in helping the child gain certain knowledge and to undergo certain emotional experiences shared with others. The technics for this sort of work are not standardized, but invite responsible research.

Mental hygiene in education is actually broader than indicated above. It includes concern about the size of classes, the condition and quality of books, the freedom of the teacher from coercive, undemocratic administration which robs him of satisfaction in his work, the inclusion of the creative arts in the educational program, as well as many other issues with which educators themselves are primarily concerned. In the presentation above, these issues have not been discussed, not because they are not important, but rather because they are implied as extensions of the attitudes set forth as more specifically defined mental hygiene.

**Industrial Mental Hygiene.** Industrial hygiene has, for the most part, not included any mental hygiene in its program. What development there has been in this field has been too often separated from programs of industrial health or medical services initiated by the industry with the cooperation of individual psychiatrists or personnel experts. It is typical of the mental hygiene in industry that it flourishes in times of labor shortage, when the objective is to keep every possible worker producing at his highest possible level, and that it tends to lag whenever the labor market is easy. This situation brings to the fore some interesting ethical problems, not properly discussed here.

The principal problems mental hygiene in industry attempts to relieve are absenteeism, labor turnover, and high accident rates. Usually high rates in any of these factors indicates low "morale" in the industry. Since standards are extremely difficult to establish for any of the factors, it is quite frequently difficult to define exact aims for a mental hygiene program in industry; too often programs are begun and proceed for years without knowing the base line from which they began, thus excluding the possibility of evaluation. A notable exception to this is the "Hawthorne Experiment" reported by Mayo and his co-workers (1933), and Roethlisberger and Dickson (1942). Perhaps the most important problem in the field is the establishment of relatively standardized methods of reporting the three basic factors so that they reflect sensitively the known changes that take place under various social conditions within the plant and also of various recruitment methods.

The fact that increased production by the individual worker is the indirect aim

of mental hygiene in industry brings up some difficult problems. It makes the mental hygienist the ally of the industry, and from a rather narrow point of view, the enemy of the laborer whose production is to be increased. The fact that increased production is the indirect result of better health may be missed and must constantly be stressed if direct opposition from unions is to be avoided. Attempts to solve this problem by promoting programs of mental health in the unions themselves have been made, but so far as is known have not achieved broad adoption. Ideally, of course, mental hygiene per se should be independent of both management and labor and apply equally in practice to both; practically, since management foots the bills, this is difficult to achieve though not impossible for those industries in which management is able to take a genuinely long-term view of its place in society.

Low morale in industry is usually found to be dependent upon two factors: first, a lack of understanding on the part of the workmen of the constructive aims and objectives of management; and second, on the personal interrelationships within the industry and in the workman's personal life. The first problem is one of communication. This problem hardly exists in very small industries when the owner is actually a fellow workman, but it presents a difficulty in large industries where there must be a hierarchy standing between the workman in the plant which may be thousands of miles away from the executive officers which control its aims and objectives. There is the foreman, the departmental supervisor, the plant superintendent, the vice-president, and frequently many others through whom communications with the "top management" must be carried out.

This issue has been attacked primarily by setting up management discussion groups which cross executive levels. In these groups the agenda do not include exclusively problems of the mechanics of production, but also include issues of employee-management relations. The rates of absenteeism and of accidents become subjects for concern as indicators of the condition of the industry's health, and as indicators of ill health in particular areas. There can then be a diagnosis of the problem and relief of it; this usually takes the form of better relationship between management as represented by the foreman, and the man at the bench. The scheme was most clearly worked out under the stress of wartime conditions and reported by the War Manpower Commission (1945). The Army furnished very numerous examples in World War II of the importance of the ordinary soldier knowing the aims of his superiors whenever possible. A special case in this area is the removal for treatment of the executive who has become psychiatrically ill or emotionally disturbed to the extent that he forms a focus for the epidemic production of low morale or actual emotional illness on the part of the workers (Giberson, 1940). Psychiatric treatment of an individual in this situation becomes an issue of prevention of disease for the group; indeed the treatment of psychiatric illness in the industrial setting has this as one of the important goals, the other being of course, the restoration of the worker to full productivity as rapidly as possible.

The second area of concern of mental hygiene in industry is low morale due to difficulties in personal interrelationships within the industry or in the family life of the individual. It is well known that family strains frequently have their origins in financial stress and it is to avoid such stresses that there are loan funds and other social services available through many industries; these are not usually identified as mental hygiene efforts though they act to relieve acute stresses on the individual.



The Hawthorne experiment demonstrated a clear relationship between the personal situation of the individual workman and variations in productivity, and developed a counselling system whereby the workman could, through interviews, share his problems with a neutral person and come to some solution of them more rapidly than would have been the case otherwise. Within the industry itself, improvement in personnel management by foremen appears to be the primary issue. The foreman is taught to judge situations in terms of the man rather than the mechanic, of the laborer rather than the labor, of the worker rather than the work. This is a more practical method of dealing with the problem for any but the largest industries. Foreman education in dealing with personnel has received considerable study and the methodology in this field is reasonably well standardized (War Manpower Commission, 1945).

Mental hygiene in industry offers some relief from the problems of labor turnover, of absenteeism and of excessive use of sick leave. It offers the possibility of control of epidemics of emotional distress traceable to a psychiatrically ill executive at whatever level. It offers the possibility of cutting down on accident rates by correcting some of the tensions which make for random rather than planned and coordinated movements and for inattention on the job which appears to be responsible for many industrial accidents.

Selection for jobs is not usually a matter of psychiatric concern in industry except on rare occasions where it may be involved in executive selection. Generally, selection is in the hands of psychologically trained personnel who use the techniques of their profession for placing workers according to intellectual and aptitude qualifications. There is increasing concern about fitting people to jobs which can afford not only satisfaction in pay, but emotional satisfaction as well, of placing people according to personality qualifications broader than those inherent in intelligence and aptitude. Thus, the gregarious person is placed in a team operation, the person who wishes to work alone is given an individual operation to perform. For the most part, this latter type of personnel selection is not well standardized. The mental hygiene aspects of personnel selection are obvious and need hardly to be discussed further.

**Mental Hygiene in Housing.** The relationship between family life and mental health has already been indicated, though far from exhaustively discussed. The opportunity for premarital counseling in connection with the serological test for syphilis mandatory before marriage in many states, cooperation with the courts in the study of threatened marital disruption, the counseling of couples who wish to adopt children or who wish advice regarding hereditary stigmata they hesitate to pass on to their children, are all areas that invite service or at least experimentation as possible services of official health agencies. As medical care programs are extended and the health department extends its cooperation in the health problems of many families, further opportunities for counseling, case finding, and in some cases psychiatric treatment will become apparent and pressing. Inasmuch as the mental health of the child is so largely a problem of the healthy living of the family, concern for the family will probably be extended in the years ahead. Inasmuch as housing so markedly affects family life, and is already a subject of concern to public health, it is appropriate to include a brief discussion of the mental hygiene of housing here.

In general, it may be said that housing ideals from the standpoint of physical

health will also, in all probability, be quite satisfactory to the mental hygienist as well. Such housing will afford maximum convenience as a means of avoiding excessive fatigue. It will provide sufficient space to offer privacy. It will be planned to include recreational space for physical exercise and allow creative activity. It will be clean, the basis for attractiveness, and be inviting, offering a place for family association. These are basic elements for healthful living for the whole man; mental hygiene has few suggestions to add.

It is a moot point whether slums are the result of poor economic conditions which are in turn due to the low quality of the people who inhabit them, or whether illness, mental or physical, acute or chronic, personal or having to do with the general economic structure, leads people to subside to a frustrated condition so that their homes become slums because of their lack of care. It is not difficult to understand how a family forced into substandard living conditions by acute adversity might find unbearable the eternal frustrations of trying to make a slum house livable and would eventually become apathetic and cease to try to improve. It is easy also to understand that children raised in slum dwellings might well reach adulthood with no other ideal for living than that in which they spent their childhood, or with no understanding of another type except in the fanciful, unavailable luxury palaces of Hollywood, or the almost equally ideal model house and kitchens used for teaching home economics in many schools. Whatever the eventual solution of the dilemma, it is clear that efforts must be made both in the direction of improving housing and of improving the quality of the people who live in the houses.

Ideally, homes should be varied enough so that they can satisfy the wishes and needs of particular families. Thus, some homes will be separate houses, others apartments or multiple dwellings. It is, of course, economically impossible to allow for such selectivity at this time. Cheap production dictates that houses shall be practically identical. It is fair perhaps to point out that the difficulty may be in economics and not in people, that changes may be indicated in the economic situation so that the satisfaction of human needs may come within the range of economic possibility. To some extent this is already happening in the programs of government housing. It is a remarkable fact that almost every ship built, except under the stress of war-time production, is designed for a particular job, whereas houses have relation to the particular family they are to house only for a very small proportion of the population living very high on the economic scale. As one looks at the seas of two and three bedroom houses now being built, and the skyscraping apartments with a thousand identical living spaces, one can sympathize with the definition given by a biologist. Riding past a development, he poked his thumb out the window and exclaimed, "Breeding pens!"

There are things to be done, however, even within the limits of the present economic setting. When it is uneconomic for each house to have space for the husband's workshop, it is possible to have shared space operated along the lines already established in communal laundries in apartment houses. This has advantages not only in furnishing a place where creativity frustrated in production line work can have a place to flower, but also makes possible the development of friendships between families and an opportunity to avoid expensive commercialized recreation. Playgrounds too expensive for single families can be established for larger housing units; at times the situation will even support a supervisor for them; this is



likely to be necessary where the mother can see her child only by looking out of a tenth story window and cannot afford the time to stay at the playground with her youngster. Nursery schools provide opportunities not available for individual families and should be an integral part of large housing units. The human animal has remarkable powers of adaptation, but it seems logical to expect that it will need some reminders of its former terrestrial life during its adaptation to living on concrete and terrazzo. These suggestions are designed to aid the adaptation.

Furniture is, of course, to be designed for durability, ease of cleaning, comfort, and beauty; but a study of any home will show furnishings that are uncomfortable, ugly, and full of dust-catching crevices because the family has become attached to them. They have become personalized in some way. This factor is receiving more recognition constantly in cases in which people must leave their own homes and go to institutions to live; they are being allowed more and more to bring with them favorite chairs and other items of furniture. Similarly, children entering hospitals are encouraged to bring a few favorite toys with them—this is extended in some pediatric hospitals to where one parent is invited to stay with the child during a short hospital stay. Planning for housing must recognize these essentially irrational patterns of behavior in human beings if people are to have homes rather than mere houses.

The attachment to a house itself is a major problem that invites a great deal of careful research. How widespread the phenomenon is has not been determined, but psychiatrists see cases in which distinct emotional depression follows moving, even though the move be to better rather than worse quarters. Moving is apparently a traumatic experience, probably symbolizing the tearing of ties in which places have been associated with experiences. Such ties are probably as strong in a slum setting as they are in higher grade housing and this sort of factor as well as the economic ones usually cited may account for the surprising finding that people may have poorer health when living in good houses than they had before they moved. Another subject for research in this field lies in what appears may be a higher rate of mental disease in children of families which live in various foreign cultures when the children are young.

**Mental Hygiene in Special Programs.** The multiplication of categorical programs in public health practice has introduced new problems of mental health that are not yet fully understood and which are difficult to discuss in a general way. In the first place, the programs which are most successful in capturing public interest and support are those which have tremendous symbolic as well as realistic significance. The heart is not only the primary organ necessary for life to continue, but it is also the word used to convey many of the deepest human feelings. It is the symbol of love; in the expression "my heart was in my mouth" it conveys fear and apprehension; through its association with blood it expresses rage in "I saw red." Poliomyelitis appeals not only to pity for the crippled, but capitalizes as well on the guilty satisfaction one has that "Thank God, I am not so deformed." That cancer is pictured as a crab, a word with multiple meanings, with all the age old symbolism that attached to that crustacean, probably accounts for some of the success in arousing public interest in the illness quite apart from its position as a statistically important cause of death. The exact mechanisms through which these factors bear on preventive and curative programs in these and other categorical programs are not

fully known. It is, however, clear that they deserve attention since such programs will certainly arouse a great deal more feeling than simple willingness to be certain of health status. Very few programs have achieved the note of victory shown in the tuberculosis poster of the girl waving the clear x-ray and happily shouting "It's great to be healthy." Most still rely on the negative predictions of disaster such as the "Tenth Man" of mental illness or the "One in Eight" of heart disease. One of the most difficult problems of health education is to balance the anxieties aroused by publicity about disease by the reassurance that follows examination or the satisfaction that comes from giving money for a cause.

Cardiac programs for children demand consideration from the mental hygiene standpoint. The child is made to act differently from its contemporaries and, unless particular care is taken, it may be denied stimuli necessary for its personality growth and development. Such stimuli will come from home teaching, occupational therapy, and care that family contacts are numerous and easy. While the ideal is that the child shall be afforded the same opportunity for social life as normal, it must be noted that this will require special effort on behalf of the child, since the illness and its treatment isolate the child from many ordinary stimuli. On the other hand, the best mental hygiene for the person in some cases of severe crippling which will likely be chronic, may be to deprive him of some stimuli in order to leave aspects of the personality undeveloped. It has been demonstrated that this happens in some instances, whether by design or accident. It would certainly appear wiser, for example, to avoid development to the level of the adolescent drive for independence in the individual for whom economic and personal independence is not imaginable. This is a special case of vocational guidance.

In the diseases affecting the young adult, of which the prototype is tuberculosis, the question will not be one of insuring or guiding personality development so much as helping an already formed personality to adapt to new circumstances and a new concept of itself (Coleman and others, 1947). The independence and feeling of self-competence won during the period of adolescence must be exchanged for an attitude of acceptance of dependency for a period, and the vanity of pride in health and self-sufficiency must be sacrificed for the period of cure and modified for a long period of years. The recognition of such factors in the clinic, together with the social and economic factors, will probably aid in recovery and make rehabilitation less difficult. It is probably wise to work out as many of the "reality problems," of how the dependents are to live with the patient so that as little independence as possible is lost. In most democratic governments treatment and restoration of health for the person contracting tuberculosis is not only a right of the citizen, but it is also the citizen's responsibility to exercise his right.

Leaving a tuberculosis hospital presents almost as many problems as entering it, and many of these have mental health components. Discharges against advice make up from 40 to 60 per cent of all discharges from such hospitals. The reasons for this high percentage of cases in which treatment is interrupted probably lie in too little attention to personality factors and environmental problems upon admission, as mentioned above, but also in inadequate medical care for the whole person in most hospital programs. This may be supplied through better occupational and educational therapy in hospitals, by better social work and by more extensive use of psychiatric consultation both with regard to individual patients and in the design of



the hospitals' general program. On the other hand, there are patients who fail in the attempt to leave the hospital, including those whose disease relapses when cure and return home is approached. The need for psychosomatic care in such cases is particularly clear (Hartz, 1944).

For a disease where the modification of mode of living is not only for a period of months but for life, the problem is not of preserving ambition to recover but rather for the modification of existence so that disability will be as little as possible, considering the pathological process underway. In diabetes, the modification will be permanent, but will affect few of the activities of the person. It is quite clear, however, that the modifications that are necessary may be a heavy burden for the person, and that abandoning treatment is a constant temptation, perhaps to be compared to the recurrent yearnings of the alcoholic to drink (Rosen and Lidz, 1949). Beyond this restless tendency to abandon treatment there is to be considered the modification of metabolism that takes place under emotional stress, modifications which may tend to make the prescribed, standardized treatment for the patient recurrently ineffective. These factors can only be approached through the method of dealing with the person through the methods described under the section above on the basic technics of mental hygiene.

In cardiac disease of older persons, as, indeed, in all aging processes, the issue is not one in which some relatively simple procedure may restore health completely, but rather one of a permanent modification in way of life and, perhaps, adjusting to the idea of death in a more intimate way than is necessary for the population as a whole. Again it is necessary for a radical readjustment of the patient's picture of himself to take place if he is not continually to be kicking against the brick wall of the restrictions placed upon him. The cardiologist would be delighted if he could achieve the sense of resignation to the impossibility of physical exertion that was so apparent in some of the soldiers seen in World War II. Many of these men had been raised on the idea that they needed to protect themselves from exertion from early childhood. The fact that study showed the early diagnosis of severe heart disability was false failed to shake their conviction that they must not exercise. Too often the concept contaminated all their lives and they were unable to do anything except care for their nonexistent heart disease and cherish their very useful neurosis.

When the problem is cancer, the issue is much different since, when the diagnosis is made, some action is necessary and is usually willingly carried out. If the curative action is not effective, there is no problem of rehabilitation, but rather one of making death as comfortable as possible and the intervening period of life as productive and satisfying as possible. The problem of the patient's knowing when an illness is a terminal one is an ancient one; many psychiatrists are beginning to feel that many more humans are heroic souls than used to be thought, and that most patients might well face death rather than be hypocritically shielded from the fact of its approach. This is a question of practice each physician has to deal with for himself and for his patient; the judgment certainly lies in the area of the mental health of both.

If the disease is cured, the rehabilitation problems will be relatively easy unless the patient has been maimed as a result of treatment. Then the issue will, of course, be the same as for the crippled or the plastic surgery patient, an area which has been extensively investigated since the war.

It may appear odd to speak of the mental hygiene problems of psychiatric illness but there are many, both for the patient and his family (Stern, 1942). The patient who has recovered from a psychiatric illness requires a great deal of rehabilitative effort, for his self-confidence is extremely severely shaken. He cannot blame an impersonal organ such as lungs or pancreas for his illness; it is a loss of compensation of his very self, his personality, that he must face. Nonpsychiatric efforts at the rehabilitation of such patients is very new and, while promising reports have appeared (Rennie and others, 1950) much further experimental work is necessary. For the family the problem is also a difficult one, because psychiatric illness frequently gives the impression of purposiveness which results in the blame of the patient for his illness. It is perhaps this factor which keeps the stigma of mental illness so strong in popular thinking. The patient is blamed for his symptoms and the family also feels some guilty responsibility for it as well. Dealing with such issues is not impossible, but since it is the personality itself which is the seat of the pathology, the problem is more complicated than in diseases on simpler levels of function.

One of the most common problems encountered by the psychiatric consultant to a health department is how to deal with the announcement that a repeat x-ray is required of a suspicious condition picked up in a survey. Is it possible to write a letter that will bring the patient in for the check-up but not alarm him unnecessarily and in a way that is not medically warranted? People, although they should know better after centuries of experience, do not expect physicians to make mistakes, and they have little tolerance for the fact that the mechanical aids to medical practice do not result in absolutely reliable findings. This being the case, there appears to be no way to avoid their anxieties when they are informed of the necessity for recheck. The problem is simply to keep this anxiety to as small a group as possible, and reduce it to a basis for action as soon as possible. Thus, every effort should be made to get the question settled quickly. As short a time as possible should elapse between the survey x-ray and the recheck—the patient's anxiety and resentment will be the greater if he thinks he has been allowed to carry his suspected disease for weeks during the red tape of processing the survey films. He will probably have little patience with personnel shortages that dictate this delay and may quite correctly come to the conclusion that a better administrative procedure ought to be worked out. When the announcement that recheck is necessary is made, it would probably be better to make an early appointment or suggest two definite alternate dates and hours rather than simply give the days and hours when the recheck can be done. This will give the impression that the patient himself is being considered, and that he is no longer one of a horde being x-rayed, but an individual selected for special study for definite reasons. The recheck should also be read as soon as possible and the information it reveals shared with the patient. If he is to get this from his private physician, a system should be worked out so that a definite appointment for this also is made at the time the plate is taken. It is necessary to arouse anxiety in order to get the diagnostic action necessary. Inasmuch as this may be useless anxiety, it should be relieved as soon as possible, and it should be tied to action designed to relieve it when it is aroused, so that if it is unjustified, the patient may be relieved completely, and if justified, further action can be taken.

The issues drawn from experience in tuberculosis surveys are applicable to other diseases as well. In diabetes surveys based on the determination of reducing



substances in the urine it has been suggested that the rate of false positives is so high that the anxiety aroused is of greater detriment than the advantage of the actual cases found. Whether this be true or not depends on one's philosophy of medical practice and public health, not on any good data at the present time. The significance of the disease in the life of the individual and the state of public knowledge about the disease in question must be considered. The public knows that diabetes is a controllable disease and a relatively large number of false positives does relatively little harm, whereas false positives in tuberculosis or cancer surveys may be of the very greatest importance in the personality function of the individual.

Finally, there are the programs of polyphasic screening, and particularly those that include a psychiatric test in the screen. Except for the psychiatric aspect, the problem is the same as discussed above, except that the administrative problems of error and time lag are increased in the polyphasic process. They are not less important in this case, however. As a generalization, it may be said that any person who fails to pass a screening test can no longer be treated as a member of a survey group; he must be considered as an individual and if the administrative structure fails to do this or is unable to do it, the survey itself should be abandoned.

Psychiatric screening with the present state of knowledge is impossible, and even if it were possible, there is every indication that the number of cases discovered would be so large that it would be impossible to adhere to the generalization at the end of the last paragraph. Polyphasic screens should not include psychiatric screening devices except under the most rigorously controlled experimental conditions and these should be used as a means of testing the screening devices and not as a means of "discovering" psychiatric illness or personality maladjustment. There are no tests now extant which are fully validated. This paragraph is not designed to cut down on very necessary, in fact, invaluable research, but this research must not arouse anxieties which psychiatry is not at all prepared to meet. As almost every administrator who is responsible for a psychiatric clinic service will testify, these services are almost invariably overloaded. Cases discovered by screening methods could not be crowded into the case load at once, but would only serve to make waiting lists longer. It should be repeated, however, that these considerations do not apply to frank research efforts set up to include the necessary care for the case found.

**Geriatrics.** Mental diseases of old age are usually secondary to organic degeneration of brain tissue, either primary degeneration or secondary to arteriosclerosis. This being the case, it might be assumed that the problem is a hopeless one prophylactically unless the basic brain pathology can be arrested or reversed. The situation is, however, not as hopeless as it appears, since there are contributing factors that may avoid and often cure the psychosis. The situation seems to be that degenerative changes lower the reserve of the brain and personality so that under stress, the personality becomes decompensated. Anything that relieves stress or tends to give support to the brain or the personality will probably be helpful in treatment and prevention. Two areas stand out as providing means for this support: nutrition, as discussed elsewhere in this volume, but it is perhaps appropriate to point out here that pellagrous psychoses frequently occur in old people and that they also frequently respond very promptly to treatment. The use of nicotinic acid as a vasodilator

tor of brain vessels is also reported to have improved brain function and thereby relieved psychotic symptoms.

The mental hygiene technics which appear to have been most effective in preventing psychoses of old age are those which offer stimulation and companionship to the elderly. Very often the aged do not fit well into the social situation \* and are lonely because they have too little opportunity to see others whose cultural background is that of their generation rather than that of their children's. Efforts to bring groups of older people together for work, intellectual stimulation and for recreation is a logical extension of health department services. This is done nowhere as an official function of the health department, but it is, nevertheless, the sort of effort that a health council might well wish to sponsor through a voluntary agency. Technics in this field are rapidly being worked out; the problem offers handholds of method and basis for further experimentation.

**Summary.** The attitude changing technics of mental hygiene are necessary for the success of most public health programs; most of the success of public health depends upon attitude changing or attitude development. The purpose of this section has been to give a few examples of using the technics and viewpoint of mental hygiene more widely in public health clinical, and, to some extent, nonclinical programs.

## THE EPIDEMIOLOGY OF MENTAL DISEASE

There seems to be a notion prevalent that nothing or very little is known about the epidemiology of the mental illnesses. This is true only in the sense that epidemiology has not solved the basic etiological problems of the most numerous and resistant types of mental disease, not that associative factors are unknown. It is also due to a tendency to remove from the concept of mental illness those diseases on which the epidemiological knowledge can lead directly to programs for prevention. Few people except the psychiatrist who has it to treat, consider paresis a mental disease; it is thought of rather as a late result of syphilis. The epidemiology of traumatic psychosis is as clear as the epidemiology of other types of accidents; it is precisely the same. The brain rather than the brawn is damaged. The mental deviations subsequent to meningococcus meningitis have the epidemiology of that disease. The list can, of course, be extended to include birth injuries, the sequelae of the encephalitides, some of the blood dyscrasias, and many others. Perhaps precisely because etiology and epidemiology of these diseases are relatively clearly understood, they tend to be looked upon as something apart from the larger groups of mental diseases.

But even for the most difficult psychiatric problem, that presented by the schizophrenic reactions, a great deal is known. Incidence of these diseases is known to be about the same in all populations thus far carefully studied, that is, in the neighborhood of 1 per cent all life incidence. All life prevalence is higher since the reactions appear early and are frequently chronic. The reactions occur more frequently in the rooming house areas where individuals tend to live alone and show a high mobility (Faris and Dunham, 1939). These reactions occur more frequently in the lower

\* See "Old Man Minnick," Ferber, Edna, in J. Strode (ed.), *Social Insight Through Short Stories*, Harper and Brothers, New York, 1946.



than in the higher economic groups, but it is not clear whether these latter two findings are due to the type of person in these groups, or whether the low economic status is the result of the symptoms of the disease. It appears that manic-depressive psychoses are somewhat more prevalent in the more responsible personality types, at least in relation to the amount of schizophrenia if not in actual incidence (Tietze and others, 1941). A great deal is known concerning the incidence of psychoses in various immigrant groups; these studies tend to indicate that the strains of acculturation increase the incidence of some types of psychoses, though there may be a relation also to the factor of the personality that leads to major migrations such as those across an ocean (Ødegaard, 1936). Alcoholic psychoses vary extremely widely in incidence in national groups, usually corresponding to the cultural pattern in those groups (Malzberg, 1940; Dayton, 1940). It is very interesting to observe the very marked difference in this regard between the figures for alcoholic psychoses in Italy, which are quite low, and those of Switzerland contiguous to the north, which are very high. This is probably related directly to the fact that little hard liquor is drunk in Italy but much wine, while in Switzerland, both wine and liquor are included in the drinking habits of the people.

The demography of the neuroses is much less well known since for these diseases hospitalization is rarely required. All of the careful studies now extant, tend to indicate that neuroses are less prevalent than psychoses, though common observation shows this to be completely false. The problem involved in accurate estimation of the prevalence of neuroses is the difficulty of definition of the illness; it is extremely difficult if not frequently impossible clinically to differentiate clearly between the "normal" and the "neurotic." No tests are available that are well enough standardized to use for surveys of population, and to get clinical judgments on any large segment of the population is a very expensive undertaking. There is some evidence that the complaint of "nervousness," as used by the public, is probably synonymous with "neurosis"; if this be granted, then the occurrence of neuroses in the population, so far as actual studies of prevalence are concerned, is between 1 and 2 per cent during any one year (Lemkau and others, 1941, 1942, 1943). Clinical estimates based on data from practicing psychiatrists and general practice case loads vary extremely widely and furnish little basis for confidence. Perhaps the most generally accepted figure is that 0.8 per cent of the population is neurotic to such an extent that treatment is indicated (Cobb, 1943).

Mental deficiency, largely because the modern intelligence test makes it possible to measure this faculty with relative ease and accuracy, has been studied extensively. It is known that rural populations show a relatively larger prevalence of mental deficiency than the urban areas, a fact not yet fully explained but possibly related to educational stimulation, to selective migration, and possibly also to inbreeding due to the relative isolation of some rural communities. Mental deficiency, defined as including those with I.Q. less than 70 "or the existence from birth, or from an early age, of mental defectiveness so pronounced that the person requires care, supervision, and control for his own protection or for the protection of others, or, in the case of children, that he, by reason of such defectiveness, appears to be permanently incapable of receiving proper benefit from the instruction in ordinary schools."

\* Definition from Report of the Mental Deficiency Committee, Part IV, His Majesty's Stationery Office, London, 1929.

occurs in the general population in from 1 to 2 per cent. It is reported as very much more common in children than adults, the reason probably being that the demands of the social order are less severe than those imposed by the requirements of success in school and to some minor extent because life expectancy is reduced in severe mental deficiency.

From these data and from experience in the practice of the care of the mentally deficient and mentally ill, it may be said with some degree of certainty that the community will require a minimum of one bed in psychiatric hospitals for each 200 of the general population and one bed for each 1,000 for the care of mental deficient.

This discussion of the demography of mental illnesses is by no means complete nor does it exhaust the literature in the field. What is attempted is simply to furnish some basic observations necessary for community planning in those areas where data are clear cut and positive.

There are particular problems in which it is clear that action based on epidemiological facts will in all probability decrease mental illness and distress; there are many others where mental hygiene efforts are justifiable on the basis of relieving distress for the particular patient and his family but the relationship to actual mental illness requiring hospitalization is not demonstrable.

The psychoses of old age represent about a third of all admissions to public psychiatric hospitals. Changing economic and social conditions in many areas, as well as because the population itself is aging, urbanization, changes in design and in the economics of housing, the changes in cultural attitudes toward the solidarity of the family, earlier retirement and the failure of the elderly to be able to find remunerative and satisfaction-affording employment and inadequate medical and nutritional care; all of these appear to be contributing factors accounting for the rise in the psychiatric hospitalization of the aged.

The demography of the psychoneurotic and other disorders not requiring hospitalization has already been discussed. Absenteeism and labor turnover in industry are known to be due in many instances to neurotic illness as well as to character disorders of other sorts (Frazer, 1947). Industrial mental hygiene can reduce these factors and can increase production, though no studies have as yet clearly demonstrated the financial advantage of such efforts to industry. There is no doubt that the programs are of advantage to the worker, however, and contribute to his morale. The fact that departments of industries in which the leadership is poor produce more "cases" for the psychiatrist than those with "good" leadership has been adequately demonstrated. Clinical observation indicates that the health service of industry, like that offered by the general practitioner, is to a large extent used by employees as a treatment center for emotional distress, even though they, and, unfortunately, frequently the medical staff as well, are unaware of the fact.

It is quite probable that there is an epidemiology of mental illness and emotional distress associated with most cultural environments and social conditions—poverty, housing, the concept of continuous advancement, the idea of universal education, etc. It is an unfortunate fact that difficulties of measurement both of these conditions and of the incidence and prevalence of mental disease, as well as the fact of multiple causation discussed earlier, have not yet yielded sufficiently to make many of the current statements in these fields reliable except in terms of clinical opinion. These



considerations do not, however, relieve organized public health from responsibility for conducting research in the area; they should rather point to the need for critical but also for creative thinking about the methods needed to do the necessary researches.

Even more remote from the area of mensuration by methods now known, is the epidemiology of fads, general anxieties, panic reactions, styles, political concepts, etc. The history of the world of the last five decades indicates how urgently knowledge in such fields is necessary. To be sure, the matter approaches philosophy and implies a definition of the goal of all humankind, but it is improbable that any citizen can escape responsibility in this area now. Perhaps the most pressing need at the moment is for an epidemiology of reaction to disaster. Studies are under way on this point and already appear to be furnishing some new understanding in the area (Cameron, 1950; Tyhurst, 1950).

### PUBLIC HEALTH ADMINISTRATION IN MENTAL HYGIENE

Administration in mental hygiene is somewhat different than in other public health programs because it inescapably involves general administrative practices within the department as well as a service to the public. The concept of working *with* a patient or client rather than *on* or *for* him demands that this same attitude be present in the administration of the department itself. Unless the department is prepared to practice good industrial mental hygiene, it cannot expect to find good mental hygiene carried out by the staff with clients and patients. The attitude of the administration will inevitably find expression in the staff-patient relationship.

Mental hygiene programs generally consist of three parts, staff education, the incorporation of mental hygiene in clinical and other services of the department not specifically called mental hygiene, and, finally, psychiatric diagnostic and treatment service to patients.

Staff education in mental hygiene is of two general types. The first has to do with the problems of human interrelationships. This is the material suggested in the section on basic technics (page 761) and it applies to everyone in the department, sanitarians, telephone receptionists, secretaries, nurses and the health officer himself. Its aim is to keep relationships within the department as well adjusted as possible so that there may be a minimum of emotional frustrations and irritations to be "taken out" on the public. It is no great secret that health departments have their fair share of difficult personalities, of jealousies, of competition that lowers morale and interferes with the productivity of the department. Mental health programs, whether by that or some other name, are designed to reduce the stresses arising from such conditions.

Efforts in this field may be specially set up for the purpose, or may be a part of general staff conferences, sometimes enlarged for the purpose. They may be led by a well informed health officer, or by an "expert" brought in from the outside a more common procedure at present. The selection of the leader is, of course, extremely important. It is not safe to assume that this sort of work can be done by any psychiatrist, social worker, specially trained nurse or psychologist, the particular person will usually have a background of training in one of these specialties but this does not mean that all so trained are either interested or capable of leading

a productive discussion. The recent advances in group psychotherapy and the study of the processes of group productivity will probably in the next few years clarify the issues involved in the selection of leaders for discussions.

Such discussions may deal directly with the subject matter of interviewing technic (Garrett, 1942) and interpersonal relationships, or they may deal with the material as exhibited in case situations reported by some staff member. For example, a very great broadening of concepts and increased understanding of society and individuals can come out of a staff discussion of a case of pediculosis, or of the refusal of a grocer to obtain his license to sell milk. The choice of method will usually be determined by the particular person to lead the discussions together with the group.

The second type of educational program for a staff is more specific and directed at a particular clinical area. The sort of material to be learned in such inservice training has been indicated but by no means exhausted in the section on mental hygiene in public health programs (page 1417). It is out of this sort of education that clinical work increases in breadth and depth so that it reaches the person rather than only the condition presenting. Suggestions for this part of the program in the health department are also contained in the section just mentioned.

The third area of mental health work in the health department is that of furnishing psychiatric treatment to the public. Ideally, such service will be carried out by the psychiatric team of psychiatrist, psychologist and psychiatric social worker. While the public health nurse with mental hygiene training may be included in this team for some purposes and will use it constantly as a source of consultation, this new specialty probably serves best in the staff education functions already mentioned; in this capacity she may also deal directly with the public in individual or group undertakings in mental hygiene, such as mothers' and fathers' groups, groups of parents of preschool children, etc. She will also act as consultant to the staff nurse and her supervisors regarding problems of interpersonal relations. The mental health nurse consultant is a relatively new specialist in the field of nursing; her function in the health department remains a matter for experimentation and the suggestions above are to be regarded as suggestions only and not as rules (Henderson, 1950; Lemkau, 1948; National Organization for Public Health Nursing, 1949).

The mental hygiene clinic presents some unusual administrative problems to the health officer. In the first place, its cost is high in terms of number of patients carried and it is difficult to fit into a tight budget structure. At the moment, it is relatively easy to arouse public interest and support for psychiatric clinic services, especially for children, and it seems likely that this will continue, because the clinic does deal with some of the most disturbing situations the community encounters and it can relieve a great deal of distress not otherwise treatable by medical science at the present time. A part of the high cost is due to the larger space necessary for psychiatric work. There must be offices which are relatively soundproof and are completely private for each of the staff persons. These offices have to be large enough to include space for play therapy materials and the latter must be provided. It is difficult to incorporate a mental hygiene clinic into the total program of the department, partly because the situation is likely to be a new one for the clinic staff itself—training in these clinical fields does not yet include very much consideration of public health practice and philosophy—and because the nature of the treatment procedures is geared so strongly to the individual rather than the group. Frustrations



arising because long waiting lists delay the acceptance of cases by the clinic tend to alienate it from the rest of the department that serves as its case finding and case referring agent. Finally, there is the problem that the personnel of the clinic establishes the close relationship with the patient necessary for treating emotional disorder and this may be resented by the referring nurse or physician. This latter problem is probably most severe for the nurse who tends to resent the intrusion of any one but the physician who enters her relationship with the patient, and for the psychiatric social worker who may well feel that the nurse has no professional right to the close relationship she had with the patient. While such problems are not unfamiliar to the health officer, and while it is probably true that they characterize the present exploratory period and will not persist when more experience has been gained, it seems well to indicate that they exist at the present time and will need attention in some situations.

The high cost of psychiatric service will probably mean that services will be shared by several communities, the aim being to have a full-time clinic team for each 100,000 of the population. Experience is already showing that this ratio will not supply the service demanded in most communities, but it is still very far in advance of services available in most areas of the country. When populations are not densely settled in cities, the clinic team will have to travel to smaller centers in order to make its services available. In general, it is believed to be almost impossible for treatment services to be effectively rendered unless cases are seen at least once a week. Therefore, planning should be done so that the team reaches each patient on its circuit at least that often if at all possible.

The modern movement to include social service consultants in the local health department offers an opportunity to combine mental hygiene with the other duties of this person, especially in small departments. Social service education generally includes enough training in psychiatric case work to allow the use of this consultant, though the ideal would be to have a fully trained resident psychiatric social worker in each community in which a clinic visits. In this situation, the effectiveness of the clinic as well as its case load may be greatly increased at relatively little increase in cost. If the specially trained social worker or mental health nurse is not available for this function, a staff nurse should be given responsibility for making appointments and seeing to it that as complete a history of the case is available for consideration of the visiting team when it arrives. Staff conferences on clinic days should include the nurse referring the case, and the persons in such other agency or agencies as the teacher, welfare department, social worker, minister, probation worker, who may be interested in the case and are available to help in making therapeutic plans and in carrying them out.

It is generally assumed that it is of advantage for all the personnel of a clinic team to be full-time employees. However this may be, it is a fact that under circumstances as they exist today it is impossible to obtain anything like the requisite number of skilled personnel necessary to meet the need if full-time personnel is the goal. Salaries in public agencies are not high enough to attract or hold the quality of trained personnel needed and it seems unlikely that the education of officials controlling salaries can be completed rapidly enough to have them raise salaries to attractive levels in the near future. A possible alternative that has positive advantages as well, is the use of part-time personnel. Many psychiatrists in private practice

are able to afford to give a day to public health clinic practice at a reduced income, both as a service to the community and as a means of extending their clinical experience. The latter consideration applies particularly to psychiatrists whose principal place of employment is in public or private psychiatric hospitals. These physicians often are extremely anxious to get outpatient, community clinic experience. Frequently, plans can be worked out with hospitals having residency programs to have residents obtain their outpatient experience in public health clinics. All of these measures are much more successful if supervision of the resident or practitioner by a qualified child psychiatrist can be offered by the clinic in question.

Clinical psychologists are also frequently available on a part-time basis. In Maryland as well as in other states, there are found to be well trained psychologists who have married and are no longer working, but who can take regular responsibility for a day or two a week in a clinic. The recruiting of such personnel is of particular advantage at this time when trained psychologists are all too few. The same situation obtains with psychiatric social work personnel.

While the part-time employee, particularly the psychiatrist, is not likely to be as well trained for his assignments as one selected for full time work, nevertheless, excellent results can be obtained in clinics organized on the principles outlined here. The team usually has but a single area to serve and it quickly identifies itself with that area, learns the organization of the community and cooperates with it to do as good a job as the situation will allow. A psychiatrist who might not be able to function in the highly organized clinic and social situation of a large city, may be able to meet many of the needs of a rural area quite satisfactorily and refer his highly complex problems to the more highly organized urban clinics. This is not to be interpreted as a plea to lower standards for personnel on the psychiatric team. It is a plea to use all available services to the fullest extent possible, realizing that it will be of different grades of excellence but that the safeguards of referral for consultation to the next medical echelon are not less operative in psychiatry than they are in general practice or hospital organization on a regional basis. It follows, to be sure, that there must be the administrative facilitation of consultation and the clinical facilities capable of furnishing it.

Administration at the state level has this as a major responsibility. The local health officer, although he should carry the responsibility for the clinic in his community if it is a health department clinic, does not yet have the training to select nor the opportunity to find personnel either on a part or full time basis except in the case of large urban centers. This is the responsibility of the state health department in most instances, or of the mental health authority if this is not the health department. Obviously, problems of distribution of clinic service to the various geographic areas and budgeting are also responsibilities which usually lie at the state level.

The state bureau or division is responsible for the inservice education of the clinic staffs and for the evaluation of their work. It is responsible for consultation services to the local health officer as regards administrative problems concerning the clinic staff, and as regards personnel problems in his department. This division will consult with the local health officer on community programs in mental hygiene and on mental health education in his community, including relations with community organizations such as the mental hygiene society, the health council, etc. In general, it will be the state bureau which plans mental health education programs



for the public, and, in collaboration with the local health officer, for inservice training in local departments.

The state division or bureau is responsible for the integration of mental hygiene principles in the work of the other bureaus at the state level. The contacts in this area will be primarily with the fields of child and maternal health, tuberculosis, and venereal disease. Personnel problems at the state level will find their way to the bureau chief's office very frequently, though these contacts are largely informal, as may be many of the other functions mentioned.

Finally, the state division will be responsible for such intensive educational programs as institutes and workshops for particular groups in the state (Ginsberg, 1950; Witmer, 1947; Maryland State Health Department, 1949). It will be responsible for cooperation with citizens groups, particularly mental hygiene societies, to help focus their efforts and to consult with them on programs.

It is not intended that the suggestions on administration in this section should be interpreted as a sort of standard operating procedure. While the principles are based on experience and study of various state programs, it must be recognized that each geographic and population unit will require planning designed to meet the problems of that unit.

The whole mental hygiene movement is barely 50 years old, the first state division of mental hygiene in a health department was set up only in 1920, and extremely few states had any organized programs before 1946, the year of the passage of the National Mental Health Act. The conclusions to be drawn from these remarks is that, while, in general, the principles set down above are of importance, there is ample room for further experimentation and for planning widely divergent from that outlined above.

In some states, the most important of which are New York and Massachusetts, the mental health authority resides in the department of the state government which is also responsible for the hospitalization of the mentally ill. There are some advantages to this arrangement; the responsibility for planning lies with the agency that usually controls the largest pool of psychiatric, psychological and psychiatric social work personnel available in the state. The mental hygiene clinic services do not form as large a proportion of the total budget for these systems as they do in the health department budget and they may for this reason be treated more generously by the financial authority of the state. On the other hand, hospital systems are generally heavily overloaded with the problem of inpatient psychiatry and are not free to give intensive study to the planning of well-integrated preventive and outpatient services. The principal difficulty in the way of the hospital system in building a competent clinic system in a state is that it has no local official organization such as the local health department with which to work. In no state in which the authority is in the hands of the hospital department has a collaborative relationship been highly developed though there is no reason why it should not be. The essence of the problem appears to be that, wherever the authority, collaboration of the health department in putting local programs into effect and of the hospital system in furnishing personnel, is essential for the success of any program (Lemkau, 1950).

**Health Education in Mental Hygiene and Selected References.** The public demand for mental hygiene material in almost every conceivable form from the pulp scientific digests of the newsstands to the slick paper magazines, from the joke

book to the sophisticated *New Yorker* cartoons, from the illicit publications on sexual technic to carefully compiled research reports by highly qualified scientists, has produced an enormous amount of printed material, beyond the reading and certainly beyond the judging capacity of any one person. Movies, both commercial and intentionally educational in purpose, are in great demand and are being produced in profusion. Very little of such material has ever been evaluated as to effect; indeed, evaluation of mental health educational materials presents extremely difficult problems, both practically and theoretically.

Health education in this field is still very largely in the hands of the psychiatric professionals. There are an increasing number of experiments attempting to use conventionally trained health educators in this field, but for the most part this type of activity is still in the hands of the psychiatrist, psychologist, psychiatric social worker, and specially trained nurse. The reasons for this are not difficult to understand. More knowledge about mental hygiene principles is, as we have seen, not the only issue in mental hygiene education; perhaps even more important is the question of attitudes. In mental hygiene these attitudes are intensely subjective and carry an extremely heavy emotional load. The question and answer period following a talk on some subject related to mental health is likely to reveal a great deal of tension in the questioner, taxing the skill of the best trained specialist to devise an answer satisfying to the questioner and the audience and at the same time not raising anxieties and straying too far from scientific truth as we know it today. These periods are likely very quickly to pass from a lecture followed by a discussion into a group therapy situation and thus test the art of the leader to a very marked degree.

Nevertheless, a great deal has been and can be successfully done by personnel below the academic and experience level of the psychiatrist. Usually, the success of these experiments lies in the restriction of the subject matter to that within the competence of the leader by announcement of topic and by selection of audience as well as by design of the leader. A trained layman might well announce the topic of feeding difficulties in children, selected with the knowledge that most of the audience would be mothers of preschool children with personal experience to share in the area of child behavior. In leading the discussion he would stick to the simpler possible factors of etiology of feeding difficulties such as the decrease in rate of growth, the difficulty of handling utensils because of the incomplete maturity of the nervous system, the common rejection of new or strange foods, etc., avoiding the more threatening possible factors such as maternal or paternal rejection, perhaps even of the competition for power in the household he may suspect in the cases. Anxieties would be relieved through the dissipation of the feeling many have that theirs is the only child with problems, through the sharing process. Indeed it is a brave—or perhaps rash—psychiatrist who will tackle the latter types of factor with any but the most highly sophisticated audience. There is a great deal of knowledge of child development and mental hygiene that is not threatening to the basic adjustment of any but the most sensitive people. It is not to be assumed that the “superficial” is not helpful to the population which is relatively healthy, and it is not to be forgotten that however frightening the statistics on the frequency of the mental illness may be, by far the largest part of the population is healthy mentally as well as physically.

Books on mental hygiene are too often actually books on mental disease. Some



of them are simply books on psychopathology diluted sufficiently for the educational level to which they are addressed. Inasmuch as most of these present a theory of etiology, they indicate a possible prevention; too often, however, the only etiology presented lies in the far past history of the sick individual so that nothing can be done about it. These books serve as case finding devices since the sick person tends to identify his own with the symptoms set forth. It is doubtful if they offer any help in a preventive sense at all. It is probable that they do inform the public of the field of psychiatry and they may help remove the feeling of stigma so frequently attached to mental illness. K. Menninger's *The Human Mind* (Knopf, 1930) is an example of the more sophisticated type of book of this kind. A pamphlet by Bingham (1949) is a more popular presentation of the same type.

Another type of book is that written by recovered patients. The paradigm of this group is Clifford Beers' *The Mind That Found Itself* (Doubleday & Co., 1948) which was an important factor in the growth of the mental hygiene movement in this country. It was a crusading book to better hospital conditions. More recent books of the same type are Maine's *If a Man be Mad* (Doubleday & Co., 1947) and Mary Jane Ward's *The Snake Pit* (Random House, N. Y., 1946). While these books allow some identification with the author and furnish some education in the mechanics and feelings of healthy and unhealthy living, they are primarily pleas for reform and not preventive in intent or, so far as can be seen, in effect. In this group fall also the book on how to be 100 per cent mentally healthy. We suspect that many of these are written by ill-informed faddists or by patients far from fully recovered. The psychiatrists see only people distressed by such works, not those helped by them; nevertheless, it is my impression that they frequently distress people by holding up an impossible ideal for which to strive which can lead only to frustration and intensification of distress.

Then there are books which attempt to define the whole field of medical practice with special emphasis on the treatment of the whole man, rather than simply of his organs. These are all too few; a good example is Binger's *The Doctor's Job* (Norton & Co., 1945) and W. Menninger's *Psychiatry* (Cornell Univ. Press, 1948) and the more ambitious *Psychiatry in a Troubled World* (The Macmillan Co., 1948).

Somewhat in a transition to types more common in the pamphlet field are those books which attempt to teach the patterns of emotional growth and development in order that the parent may anticipate and be prepared for what is coming as the child matures. An early example of this type is the Aldrich *Feeding our Old Fashioned Children* (The Macmillan Co., 1941) and the more recent and extremely popular *Infant and Child Care* by Spock (Duell, Sloane & Pearce, N. Y., 1945). Another example is Lerrigo's *Children Can Help Themselves; The Normal Child's Health Behavior* (The Macmillan Co., 1944), Jenkin's *These are Your Children* (Scott, Chicago, 1949), and the old but helpful *Parents Questions and Answers* by Gruenberg (Harper and Bros., N. Y., 1936).

Pamphlet literature can mainly be divided into three types. The first is that devoted to propaganda for hospital reforms and for the changing of attitudes toward mental illness. Many of the publications of the National Mental Hygiene Foundation\* in recent years have been devoted to these ends. A second type is devoted to

\*Now the National Association for Mental Health, 1790 Broadway, New York 19, New York.

giving general information about behavior disorders and mental illness but also to the psychological exploration of the importance of some features of living in the production of stresses and strains which may result in behavior disorder or illness. An example is *Mental Health is a Family Affair* (Pratt and Neher, Pub. Affairs Comm., N. Y., 1949). The third type deals with childhood behavior and the trials of parent and family that normal child behavior induces. There are many excellent examples of this, such as the series prepared by the New York Committee on Mental Hygiene, *Some Special Problems of Children Age Two to Five Years* (Ridenour and Johnson, National Mental Health Foundation, N. Y., 1947), and a short but similar series called *Babies Grow in Eating Habits* and *Babies Grow in Toilet Habits* (National Institute of Mental Health, U. S. Public Health Service, 1949). In general these pamphlets are cheap and are suitable for distribution through the usual literature racks in the health department.

A special note is deserved by the series of pamphlets of the latter type called *Pierre the Pelican* (Rowland, 1947). This was devised by the Louisiana State Health Department and is sent at monthly intervals to the parents of each child born in that state—as well as other states which buy the material from its publishers. One of the few attempts to evaluate such material has been made on this series by Rowland in the *A First Evaluation of the Pierre the Pelican Mental Health Pamphlets* in 1948. The research by no means meets the requirements of vigorous scientific method, but it does point the way for further studies. A series of pamphlets for prenatal distribution is now available also.

Larger displays, such as posters and exhibits are relatively new and may again be divided into those concerning hospital reform and those designed to give information about child growth and development. An interesting series of the latter type is that being published by the North Carolina Hospitals Board of Control. It deals very briefly with various behavioral problems advising one to *Find the Cause* (Raleigh, N. C., 1949). Again, there is real question as to how much effect such material actually has in teaching or reassuring; the problem invites serious research.

Newspaper material on mental hygiene presents such a kaleidoscopic variety that it is difficult to deal with in a brief space. The oldest and possibly the most widely read of such material are the “advice” columns. These have been recognized as having a good deal of influence but generally have been looked upon as somewhat below the dignity of scientific study and evaluation, though recently they are receiving some study, particularly as applied to marital problems (Mace, 1950). Along with these are the “psychology” columns which may be informative but too frequently, after they have run a few months or years, abandon their policy of teaching experimentally demonstrated facts to indulge in quotations of opinion no better than the “advice” columns. Feature stories about new treatments or treatment in institutions, clinic systems, etc., undoubtedly help inform the public about available services. Series of articles or columns on child care frequently are helpful and reach more people than do pamphlets on the same subject.

One type of newspaper material, also used in magazines, about which there is some difference of opinion concerns the “exposé.” Typically, this is an explosive burst lasting a few weeks, telling about conditions which exist in the public hospitals. The series aim is arousing the public to demand reform and this is usually frankly admitted by the writers to be done best by presenting only the shocking and not the



satisfactory or the good in the hospital or the system under study. Frequently, such series are a very powerfully effective impulse to momentary reform and genuine improvement. The danger in them lies in the possibility that the continuous vigilance and public sense of responsibility necessary for the maintenance of good hospitals will be neglected, it being assumed that the immediate reform will be enough to last; it never can be. The second danger is comparable to that discussed under screening procedures in public health: does the negative publicity arouse so much fear in the population that patients who can profit by hospitalization fail to reach the hospital? Dr. Kenneth Jones, for years a psychiatric hospital superintendent, once said that if he could only get the name of his hospital before the public he would not care at all what was said about it. He believed public apathy to be the greatest evil and anything that decreased it and improved public awareness was an asset. There is much to be said in favor of this view, for certainly public apathy is any institution's greatest enemy.

Movies have, in the last few years, received a tremendous amount of attention as means of public education. One great problem in this field is that it appears almost impossible to make movies in the field for a special audience if they have any dramatic appeal—they always get to the public, whether made for it or not. It is now generally agreed that no film on mental hygiene can stand alone. Whenever one is shown it should be followed by a discussion period, the leader of which can answer questions and, if necessary, dissipate the anxiety the film will almost certainly arouse. The National Institute of Mental Health of the U. S. Public Health Service has prepared an extremely useful catalogue (1949) of films about mental health and mental illness, as has the National Film Board of Canada.

The radio has furnished admirable examples of public education in mental health. The major broadcasting companies in the U. S. have occasionally sponsored special programs in the areas which are known to have had considerable audiences though their effect is unknown except that they were well received.

A set of "platters" for local sponsorship and broadcast has been prepared for each of the last three years by the National Mental Health Foundation.\* These series have shown steady improvement from the first to the third series. They have the advantage of local sponsorship which means a local drive for listeners, but the disadvantage is that local public service time is usually not at optimal radio time to reach a wide audience. Nevertheless, these series offer real opportunities to local groups interested in the education of the public.

Discussions of mental health material of nondramatic type on the air generally fall into the categories of speeches and group or panel discussions. Unless the speaker is famous, the former are generally agreed to be quite ineffective in holding listeners. The latter, partaking as they do of some dramatic technic and emotional force, are more likely to hold listeners. Programs of this sort are often arranged locally but also occasionally appear on the established national forum programs.

In summary, it may be said that the public appetite for educative material in the field of mental hygiene is very great and that there is a great deal of material ready to try to satisfy that need. Little of the material can stand alone; most of it needs to be accompanied by someone equipped to interpret it and to deal with the

\* See footnote on page 796.

anxieties it arouses. Almost none of the material has been tested for effectiveness in changing attitudes or in giving information, and it must, at present, be judged according to local needs and opportunities. Evaluation of such materials is very greatly needed; research is necessary in the field of method of testing as well as in the effect of any particular material used.

## SUMMARY

The preservation of mental health and the prevention of mental disease is an inescapable responsibility of public health inasmuch as mental illness and behavior disorder are the cause of tremendous morbidity and costly hospitalization. Prevention of many mental illnesses is clearly understood in terms of direct etiology, and programs in these areas have been notably successful. Those illnesses of multiple, psychogenic etiology present difficult practical problems. These are now best attacked through efforts to improve the mental health of the family through improved parental and parent-child relationships through health department, school and other programs, through efforts in industrial mental hygiene and by improving the social opportunities of the elderly. Many of the health department clinics are directly related to family health and have great opportunities to influence family relationships helpfully.

Specific mental hygiene programs will deal in the administrative health within the department itself, since the attitudes established here will influence for good or ill the ultimately effective relationships in clinic or home. There is also a mass of information in the field of mental hygiene that needs to be known by the various categories of personnel in the department, and which can be taught in inservice training programs which allow for the necessary setting in which attitudes may be changed or can change.

Difficult still to bring to a pointed, clear-cut program for attacking a very great area of health preservation, mental hygiene is rapidly becoming more defined and definable. While a very great deal of research is still necessary in all its ramifications, patterns for constructive action are not lacking.

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## Section Four

# FOOD SANITATION

## 21

### FOOD INJURIES AND THEIR PREVENTION

In addition to the nutritional disturbances which are due to improper dietary habits, consumption of food may cause injury to health in a number of other ways. Probably the most frequent cause is allergy to specific protein substances. It is not uncommon to find individuals sensitive to seafood, strawberries, eggs, tomatoes, milk, and a variety of other dietary substances. The degree of sensitiveness varies widely, as does the severity of manifestations following consumption of an article to which an individual is sensitive. The allergic manifestations vary from scarcely noticeable urticarial wheals, or hives, furring of the tongue, ulceration of the mucous membranes of the mouth to such distressing symptoms as generalized urticaria and angioneurotic edema, eczema, asthma, hay fever, migraine, anaphylactoid purpura, etc. The reaction or illness is not due to any fault in the food but to personal idiosyncrasy. One man's meat may be another man's poison. The prevention and treatment of conditions such as these are the concern of individual patients and their physicians.

Eliminating nutritional disturbances and allergies from consideration, foods may serve as a vehicle for the transfer of pathogenic microparasites from one host to another. The biologic agents are present simply as contaminants, undergoing little if any multiplication in the foodstuff. Numerous examples have been cited in chapters on the control of communicable diseases in connection with the discussions of typhoid fever, salmonellosis, bacillary and amebic dysentery, cholera, diphtheria, streptococcal infections, Q fever, etc.

In similar manner, food may serve as the means of transfer of animal parasites. *Trichina* and tapeworms occur as antemortem infections in the flesh of the food animal. Plant foods may be contaminated with the eggs or larvae of parasitic helminths, some of which are capable of developing in the human body. The measures required to prevent the transmission of pathogenic micro-organisms and parasitic helminths through food as a vehicle are discussed in connection with each specific disease and parasitic cycle.

### FOOD POISONING

Food poisoning is a general term used to designate illness (commonly acute gastro-enteritis) due to the consumption of food containing deleterious chemical substances. There is a wide range of such substances. They may be naturally present in plants or fish which are eaten through mistake or in ignorance of their dangerous characteristics. Chemical poisons may be introduced into foods accidentally or with malice aforethought. But by far the most common form of food poisoning, however

is that due to toxic substances which are produced by the growth of certain bacteria in foods.

Insofar as certain varieties of foods may at times contain natural poisons or be accidentally contaminated with poisonous chemicals or the toxic products of bacterial growth, and groups of individuals may be actually or potentially exposed to the injurious effects, it becomes the concern of public health to exert every effort to protect the consumer. This is accomplished in part by the administrative enforcement of laws and regulations with regard to the conditions under which such foods are produced, processed and distributed, and in part by education of the general public as to the possible dangers and necessary precautions in the preparation and handling of food for human consumption. The laws and regulations are intended to protect the public not only against injury to health but against fraud and deceit. They restrain the sale of foods which are decomposed, adulterated, improperly preserved or misbranded. They provide specifically for the safe handling of such perishable and potentially dangerous foods as milk, milk products and meats. Finally, methods and procedures have been developed to reduce to a minimum the danger of contamination of foods with poisonous substances or with pathogenic micro-organisms.

#### FOOD DECOMPOSITION

Decomposition of food is usually the result of bacterial activity, but it may take place also as a result of physical, chemical or electrical agencies. The law condemns food that is "filthy, putrid or decomposed." The word "decomposition" is not used in a technical sense in the National Pure Food and Drugs Act of 1906. There it has the meaning used in ordinary everyday parlance. It is difficult to determine just where to draw the line between technical decomposition and objectionable decomposition. We purposely permit many foods to decompose. Meats are hung three days or longer in order to render them more tender and improve their flavor. Some prefer meat when highly decomposed or gamey. The gourmand hangs his pheasant by the tail and waits until it drops off. Bread, cheese, buttermilk, sauerkraut, vinegar, cider and many other foods are products of decomposition. Our principal concern is decomposition that may be harmful to health.

**Fermentation and Putrefaction.** There are very many kinds of decomposition. Two main groups are recognized: (1) fermentative decomposition and (2) putrefactive decomposition.

Fermentation refers to the breaking down of carbohydrates with the formation of acids (lactic, acetic, butyric), alcohol, carbon dioxide, etc.

Putrefaction, from *putrere*, to be rotten, is literally a process of offensive decay. It is generally restricted to include only those processes of protein disintegration which give rise to foul-smelling products. For practical purposes, it consists of the decomposition of organic matter, usually protein in character, due to bacterial action.

Pasteur pointed out that putrefaction is essentially an anaerobic process. This has since been abundantly confirmed. Rettger insisted that putrefaction is the work of certain obligate anaerobes, which are able to initiate and carry on the decomposition of native protein. They include particularly several species of large, Gram-positive spore-formulating rod-like bacteria classified as clostridia and found widely distributed in nature as soil organisms—*C. perfringens*, *C. histolyticum*, *C. sporo-*



*genes*, and others. Certain aerobes, such as the proteus family, the colon group, and the subtilis group, also play a part, although they cannot initiate changes in protein

The end products of putrefaction are ammonia, nitrates, carbon dioxide, hydrogen sulphide, methane, etc., all simple, stable compounds which in the concentration ordinarily found in decomposed food are not injurious. The intermediate cleavage products of putrefaction have been suspected. Each particular micro-organism breaks down organic matter in a specific and limited way. Ordinarily these processes result from a combination of bacterial actions in which aerobic and anaerobic organisms each play a part in turn.

**"PTOMAINÉ" POISONING.** Ptomaines are secondary cleavage products of protein putrefaction. Vaughan defined a ptomaine as an organic chemical compound, basic in character, and formed by the action of bacteria on nitrogenous matter. On account of their basic properties, ptomaines give some of the reactions of the vegetable alkaloids and have, therefore, been miscalled putrefactive alkaloids. They are sometimes called "animal" alkaloids, but this too is a misnomer, for they also are formed by the putrefaction of vegetable protein.

The term "leukomaine" is used to cover the same or similar basic substances which result from tissue metabolism within the body; that is, leukomaines are produced in the living body, ptomaines in dead organic matter.

The word "ptomaine" was coined by the Italian toxicologist, Selmi, in 1870, from *ptoma*, a corpse. He used the word to describe basic poisonous products analogous to the familiar alkaloids of plant origin. The further exploitation of the expressive word "ptomaine" was largely the outcome of studies by Gautier in 1872, who also introduced the term "leukomaines."

Ptomaines, in sharp contradistinction to toxins, are nonspecific, that is, they are not the products of intracellular metabolism characteristic of the micro-organisms which produce them. They are merely decomposition products of the protein molecule and are elaborated by all bacteria that are capable of producing this degree of protein cleavage when grown on suitable nutrient media and under favorable conditions of growth. They may be produced by bacteria which possess no pathogenic power, while on the other hand highly pathogenic bacteria which are not active in attacking protein may produce few or no ptomaines.

The term "ptomaine poisoning" is a misnomer. Savage stated that the term ptomaine poisoning is clearly incorrect, and Jordan stated that ptomaine poisoning is a refuge from etiologic uncertainty. Vaughan agreed with Jordan and Savage that the term ptomaine poisoning is incorrect and should not be applied to food poisoning. Novy stated that "the rather popular expression 'ptomaine poisoning' is a survival of the period when it was believed that bacteria produced their injurious effect by means of basic or alkaloid-like products. Long ago the importance of ptomaine disappeared, due in the first place to the discovery of toxins, and in the second place to the fact that these substances are not secondary products of protein cleavage. Chapin stated that ptomaine poisoning is a good term to forget.

Ptomaines include substances which are chemically very different. The classification is unscientific and abandoned by chemists. A few of them are physiologically active, even poisonous when injected parenterally. None of them is actively poisonous when taken by the mouth, and even the active ones do not produce nausea, vomiting, colic and diarrhea.

It is not *decomposed* food that may be dangerous, but foods prepared under conditions that favor the growth of certain kinds of bacteria.

**Bacterial Food Poisoning.** The growth of certain kinds of bacteria in foods may be injurious in two ways. First, if the conditions are favorable, small numbers of a potentially pathogenic species introduced through contamination may undergo multiplication so that when consumed by man he becomes infected with a dose which is temporarily overwhelming. This form of food poisoning has been discussed under Salmonellosis (see page 216). Second, if conditions are favorable, species of bacteria which are ordinarily noninvasive and relatively nonpathogenic for man may grow in certain foods and elaborate toxic substances which when ingested give rise to serious, even to fatal disease. These bacterial food intoxications are of two types: that caused by the enterotoxin of staphylococci, acting as a violent gastro-intestinal irritant, and that caused by the exotoxin *C. botulinum* which has an affinity for the central nervous system and gives rise to progressive muscular weakness and paralyzes in the symptom complex known as botulism.

#### STAPHYLOCOCCUS FOOD POISONING

Up to about 20 years ago attention was largely concentrated upon the Salmonella and Clostridia as causes of food poisoning, although other bacteria were suspected. Barber (1914) reported that he had found that milk drawn from one quarter of the udder of a cow which had been the seat of an attack of mastitis a few years previously contained a white staphylococcus which was responsible for sporadic cases of acute gastro-intestinal upsets on a certain farm in the Philippine Islands, during the years 1909 and 1913. This organism developed in sufficient numbers to be serious only in unrefrigerated milk and cream. A toxic substance was liberated which could be demonstrated only by feeding experiments in human volunteers. These findings, however, remained unappreciated for 15 years. The role of the staphylococcus in food poisoning was reopened by the investigation of an outbreak in Chicago affecting four different families which was traced to the consumption of three layer sponge cake with a thick cream filling (Dack and others, 1930). A bacteriological examination of this food revealed 19 different types of colonies. Three of these were further studied, as they were predominant. A filtrate from a veal-infusion broth of only one of these, incubated 40 hours, produced typical symptoms in a human being, beginning three hours after drinking a 25 ml. portion. The organism from which the toxic filtrate was prepared was a yellow hemolytic staphylococcus. This was the beginning of a long series of observations made by a number of investigators which established beyond question the role of staphylococci in food poisoning. It became apparent that they were the commonest cause of outbreaks of acute gastro-enteritis following consumption of contaminated foodstuffs. For example, in a recent analysis of outbreaks reported to the U. S. Public Health Service (Feig, 1950), out of a total of 476, in which effort was made to ascertain bacterial cause, 368 were attributed to staphylococci. Almost 80 per cent of all reported outbreaks of gastro-enteritis belong to this group.

**Incubation Period.** Symptoms usually appear in two to four hours after ingestion of the incriminated food; although the time interval varies from 1 to 11 hours. About 90 per cent will have symptoms within eight hours.



**Symptoms.** The onset is abrupt and sometimes violent with salivation, nausea, vomiting, prostration, abdominal cramps, and diarrhea of varying severity. In mild cases there may be nausea and vomiting without diarrhea, or there may be cramping and diarrhea without vomiting. There is usually little or no elevation of temperature; in fact, the temperature is more likely to be subnormal. Even with the same dosage, individuals may vary widely in the severity of their reactions. Ordinarily, the symptoms persist for several hours. The patient usually feels quite well in 24 hours after the beginning of the attack, although weakness and nausea may persist for a day or two. In normal children or adults, fatalities are extremely rare. Nearly every one is susceptible to this form of food poisoning. In outbreaks, attack rates are very likely to be high. It is doubtful whether an attack confers immunity; the same individual may have repeated attacks.

**Diagnosis.** A characteristic feature of staphylococcus food poisoning is the shortness of the time interval between eating the contaminated food and the onset of symptoms. In an individual it cannot be differentiated from acute gastro-enteritis due to other causes by any laboratory test now available. When several cases occur in a group of persons who have eaten together on some occasion, the diagnosis may be established by epidemiological evidence. When such an outbreak occurs, inquiry should be immediately instituted to obtain the list of foods served at the meal in question and information obtained regarding which article of food each individual consumed and whether or not he was subsequently ill. By such an inquiry it is frequently possible to ascertain the food which was responsible. With good fortune, in some instances, a portion of the suspected food is still available and the sample can be submitted for laboratory examination (Am. Pub. Health Ass'n, 1950). In the event that the food is responsible for the poisoning it will usually be found to contain hundreds of millions of staphylococci per gram. This by itself, however, does not afford conclusive proof. Staphylococci are ubiquitous; millions are contained in many foods without causing illness, since many strains do not produce enterotoxin. A conclusive test must demonstrate that the strain of staphylococcus recovered is capable of producing enterotoxin.

**Enterotoxin.** Methods for the identification of enterotoxin-producing staphylococcus have been extensively explored. Various cultural characteristics have been studied. Oral administration and parenteral injection of various species of animals have been tried. The use of monkeys and kittens for this purpose has been found to be highly suggestive, but interpretation of the results of tests on these experimental animals are fraught with difficulty and uncertainty. No test has yet received the sanction of common acceptance for routine laboratory use. The presence of small amounts of enterotoxin can be detected only by administering the suspected material to human volunteers; but this procedure is not to be lightly undertaken. Serious illness has occasionally resulted from such tests.

Nevertheless, by the use of human experiments, some of the qualities of the enterotoxin have been established (Dack, 1949). Empirically, certain foods may support the growth of staphylococci without the production of enterotoxin as, for example, canned salmon. Others, such as cured meat products and custard filled bakery goods, allow food poisoning staphylococci to grow well and produce enterotoxin. Aside from such empirical knowledge, however, little is known of the cultural requirements for the production of the enterotoxin. Enterotoxin, which was pro-

duced by growing a strain of staphylococcus in beef-infusion broth incubated aerobically, was boiled for 30 minutes. When 2 and 10 ml. were fed, respectively, to two human volunteers, typical symptoms occurred in both. Limited though this experiment be, it suggests that the enterotoxin is extremely resistant to heat.

**Source of Contamination and Kinds of Food.** Staphylococci are found widely distributed in nature. They are frequently found in the secretions of the nose and throat of human beings and may be present in large numbers as a result of chronic infections of the nasal sinuses. They are the cause of localized skin infections, boils and carbuncles. They are often in the dust and air of rooms. It is, therefore, practically impossible to trace the source of contamination of a food.

Foods implicated in staphylococcal food poisoning are chiefly pastries, milk and milk products; meats (particularly cured hams) and pastries containing custard or cream filling are frequent offenders. A number of outbreaks have been traced to meat or meat sandwiches. Most of the outbreaks due to milk have been from the consumption of raw milk.

**Prevention.** For the production of food poisoning there are three principal requirements. First, there must be sufficient contamination of the food with enterotoxin-producing staphylococci; second, the food must be a good medium for the growth of organisms and production of enterotoxin; third, the food must remain at about room temperature or above for several hours.

Prevention depends upon reducing so far as is possible the risk of the realization of these three conditions by appropriate methods of preparation. Due to the ubiquitous distribution of staphylococci very little can be done to prevent their introduction into the kitchen. Food handlers with infectious nasal discharges or purulent local infections of the skin should be excluded from this kind of work until healing has taken place. Cleanly methods and the use of various kinds of covers to exclude dust will reduce the risk of contamination with enterotoxin-producing staphylococci. Foods should not be permitted to stand at room temperature or above any longer than is necessary. Refrigeration at a temperature below 10° C will prevent the growth of these micro-organisms. Where refrigeration is undesirable, as is the case with certain bakery products, cream fillings, custard puffs and éclairs, special precautions are necessary. Methods have been developed for reheating puffs and éclairs for a period of time and at temperatures sufficient to kill staphylococci without impairing the flavor and appearance (Stritar and others, 1936; Gilcreas and Coleman, 1941).

When cured hams leave the packer they are safe. When they have been partially sliced they may easily become contaminated with staphylococci. At room temperature these organisms grow very well in ham without producing signs of spoilage as evidenced by odor or taste. The necessity of protection by refrigeration is obvious.

### BOTULISM

Botulism is a specific toxemia caused by the toxin of *Clostridium botulinum* (formerly *Bacillus botulinus*). The bacillus grows in a great variety of foodstuffs, both of plant and animal origin, and produces its poison in the food before it is eaten. The name botulism (from *botulus*, a sausage) has lost its original significance.

Botulism stands out as a distinct type of food poisoning. The bacillus itself is essentially a harmless saprophyte. Botulism further differs from other forms of



bacterial food poisoning in that the attack is chiefly upon the central nervous system. Acute gastro-intestinal disturbances usually do not occur. There is no fever.

A history and review of the literature from early times up to 1918 is found in Dickson's (1918) monograph, and for the decade following in an article by Meyer (1928).

**Etiology.** The cause of botulism was demonstrated by van Ermengem who studied a series of cases which occurred at Ellezelles, in Belgium, in 1895. In the first of these outbreaks, 23 persons became ill and three died after eating ham which had been preserved in brine. From portions of the ham and from the spleen and intestinal contents of one of the victims, van Ermengem succeeded in isolating a Gram-positive, spore-bearing anaerobic bacillus, to which he gave the name *Bacillus botulinus*. He found that infusions of the macerated ham and bouillon cultures of the bacillus produced the typical symptoms of botulism in guinea pigs, rabbits, cats, pigeons and monkeys. The bacillus itself he believed to be a saprophyte, and the poisoning to be due to a toxin which is formed when it grows in food under anaerobic conditions.

**Prevalence.** Botulism has been recognized by German clinicians since 1735, when the first authenticated case was recorded. The outbreak which first attracted the attention of the medical profession occurred in 1793 in Wildbad in Württemberg, where 13 persons became ill and six died after eating sausage packed in the stomach of a hog, and which contained a great deal of blood. The number of cases reported in Germany is as follows:

YEARS	CASES	DEATHS
From 1793 to 1820 .....	76	37
From 1820 to 1822 .....	98	34
From 1822 to 1886 .....	238	94
From 1886 to 1913 .....	about 800	about 200

It became apparent that botulism occurred throughout the civilized world. Meyer has collected data on 483 outbreaks occurring in the United States and Canada between 1899 and 1949. The distribution is shown in Table 21-1. During the past decade there have been about 12 to 15 outbreaks each year.

Botulism is one of the causes of forage poisoning in horses, and of limberneck in chickens and turkeys, and may also be responsible for various types of paralysis in domestic animals, including dogs.

**Period of Incubation.** The symptoms usually appear from 18 to 36 hours after ingestion of the poisonous food. However, cases are on record in which the incubation period has been as short as four hours or as long as six days. There is a direct correlation between the severity of the poisoning and the period of incubation—short period indicates a severe and often fatal intoxication. In a series of 246 cases collected by Geiger, of which 173 resulted fatally, 147, or 85 per cent, of the fatal cases were persons in whom the period of incubation was less than 48 hours.

**Symptoms.** The earliest symptom is usually a peculiar indefinite indisposition associated with a feeling of fatigue, sometimes headache and dizziness, and definite muscular weakness. When the period of incubation is short, the first symptoms may be gastric distress, nausea, vomiting and occasionally diarrhea, which, however, a

Table 21-1. Botulism in the United States and Canada. Total incidence by states, 1899 through 1949

Location	No. of Outbreaks	Location	No. of Outbreaks
California	184	South Dakota	3
Washington	61	Texas	3
Colorado	31	Wisconsin	3
Oregon	26	Alabama	2
New York	25	Arizona	2
New Mexico	22	Missouri	2
Montana	13	Nevada	2
Nebraska	9	Virginia	2
Tennessee	9	Arkansas	1
Wyoming	8	Florida	1
Idaho	7	Georgia	1
Illinois	6	Iowa	1
Michigan	5	Kentucky	6
North Dakota	5	Maine	1
Ohio	5	Minnesota	1
Canada	6	Mississippi	1
Massachusetts	4	Oklahoma	2
New Jersey	5	Washington, D. C.	1
Pennsylvania	4	West Virginia	1
Utah	5	Maryland	1
Connecticut	3		
Indiana	3	TOTAL	483

From Meyer, K. F., and Eddie, B., University of California Medical Center, July, 1950.

transient. Botulism differs from the common type of food poisoning, in that there are usually no indications of acute gastro-intestinal irritation. Constipation is almost constant.

Disturbances of vision occur early, and are scintillation and dimness of vision, sometimes progressing to blindness, due to impairment of both the extrinsic and intrinsic muscles of the eye. The third cranial nerve is early involved, causing blepharoptosis, dilatation of the pupils, loss of reflex to light, and diplopia. Loss of accommodation soon becomes complete. Nystagmus, strabismus, vertigo and, sometimes, photophobia occur. The ophthalmoplegia is merely a phase of the more general paralysis, but is a conspicuous symptom, owing to the striking character of its manifestations.

Coincident with, or closely following the onset of disturbances of vision, the patients complain of difficulty of swallowing and talking, and frequently there is a peculiar sensation of contraction of the throat. The mouth is dry and attacks of strangling occur. Thick, glairy mucus, with dryness of the throat leads to an ineffectual cough. The breath is offensive and fetid. Complete paralysis of peristalsis causes the stubborn constipation.

A striking feature is the progressive muscular weakness, which in severe cases closely simulates paralysis. Incoördination of muscular movement is common. The paralysis is usually of the ascending type, manifesting itself first in the intestines, perhaps due to involvement of the mesenteric plexus, then gradually passing upward, progressively involving higher centers, until the medulla is reached. The motor areas



seem almost never to be involved, although in the Montana outbreak paralysis of the right arm and leg was observed.

The *loss of nervous tone* manifests itself in vague, indefinite indisposition, marked fatigue, dizziness, headache, restlessness, indefinite sensations of chilliness, incoördination and unsteadiness in walking with a tendency to a "steppage" gait, great muscular weakness and sometimes urinary incontinence. The ophthalmoplegia may be partly responsible for some of the above symptoms.

Botulism is characterized by an almost complete absence of sensory disturbances. It is unusual to suffer pain, and the mind remains clear.

Inhibition of many of the secretions, especially saliva, sweat and tears, is an almost constant manifestation of botulism. Oliguria has been noted.

The pulse is usually rapid, and the temperature subnormal. Fever developing late in the poisoning indicates bronchopneumonia. Respiration at first is not impaired but later in the course of the illness disturbances of respiration become severe. Difficult articulation and perhaps complete aphonia, accompanied by an inability to swallow, soon appear, due to paralysis of the laryngeal and pharyngeal muscles. Increasing difficulty in breathing, leading eventually to death due to paralysis of the respiratory center, brings the scene to a close.

The general appearance of the patient is distressing; the muscular weakness, the anxiety and utter helplessness, the difficulty in swallowing, the attacks of strangling, the struggle for breath, with its resulting cyanosis, and the unsuccessful attempts to articulate constitute a clinical picture which once seen can never be forgotten. It is essentially that of a bulbar paralysis, with the earliest symptoms indicating injury high up in the brain stem. The disease must be differentiated from other causes of bulbar paralysis and ophthalmoplegias, such as encephalitis lethargica, poliomyelitis, cerebrospinal syphilis; also poisoning from belladonna, gelsemium, hyoscyamus and methyl alcohol. There is no constant pathologic lesion.

The duration varies greatly. Death may occur in 48 hours after eating the poisonous food; as a rule, it occurs in from four to eight days, and few die after 10 days. Dickson reports one death on the twenty-sixth day. Death usually is due primarily to respiratory failure. Convalescence is extremely slow and tedious, and the disturbances of vision and weakness may last for months.

The *case fatality rate* in botulism has varied in different outbreaks, depending upon the amount and virulence of the toxin. In the United States it is approximately 65 per cent, and surprisingly uniform.

The *Bacillus. Clostridium botulinum*, discovered by van Ermengem in 1895, is a large, slightly motile rod with rounded ends; four to eight flagellae, generally single, rarely occurs in filaments; stains readily, and is Gram-positive. It is anaerobic. The spore is large, polar and a true endospore.

The bacillus grows well at room temperature, between 20° and 30° C, but also thrives at 37° C. Contrary to previous opinion, it may grow in the body. It is a strict anaerobe. It grows under special conditions in symbiosis with certain aerobic bacteria, such as a white sarcina (van Ermengem) or with *B. subtilis* (Romer); and freshly prepared bouillon under aerobic conditions if a piece of sterile flesh or potato is placed on the bottom of the culture tube. The addition of glucose to the culture medium greatly increases its activity in growth and in toxin formation. In a medium consisting of one part sheep's brain and two parts water it grows well at

produces an abundance of spores. The strains studied by van Ermengem produced practically no change in the appearance of milk, but von Hibler and others find that milk casein is precipitated and peptonized. It is strongly proteolytic, and a putrefactive odor is given off. Gas which is usually formed is due to the fermentation of sugars in the medium. The 21 cultures studied in Rosenau's laboratory showed minor differences in cultural characteristics; only 10 of these strains produced toxin. Atoxic strains must be differentiated from *B. sporogenes*.

**TYPES.** Five types have been differentiated on the basis of specificity of their toxins. They are classified as *Clostridium botulinum* or *parabotulinum* types A, B, C, D and E. Animals immunized with a toxin of a specific type produce antitoxin in their serum which will neutralize only that type of toxin. Human botulism has been found to be due to types A, B and more recently E. No human outbreaks of botulism have been traced to types C and D.

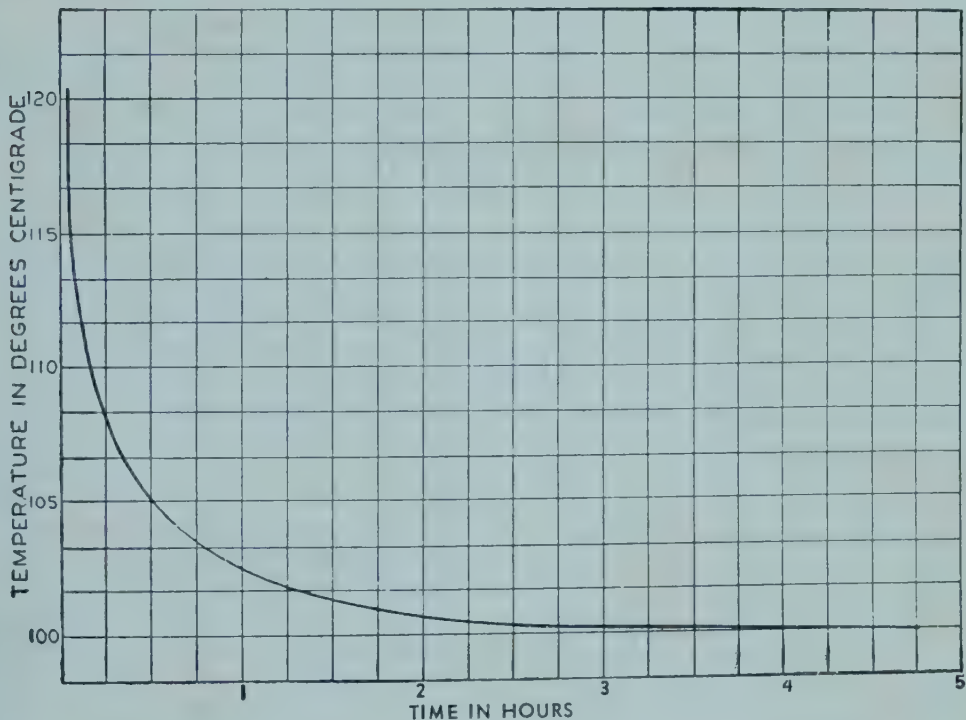


Fig. 21-1. Curve 1, showing thermal death point of *Clostridium botulinum*.

**HABITAT AND DISTRIBUTION.** The spores of *C. botulinum* are widely distributed in nature. They are found in soil, on fruit and vegetables, in the larvae of worms, in dust and on food. They have been found in many parts of the world, even in the virgin soil of mountains. The habitat and distribution resemble those of other intestinal spore-bearing anaerobes, such as tetanus and the gas bacillus. Meyer and Dubovsky (1922) made an analysis of 1,538 samples of soil, vegetables, feed and manure collected from every state of the United States except Virginia. Briefly summarized, their conclusion from this survey was that the soil of the western states inclusive of the Great Plains, yield mainly *C. botulinus* type A, while in the Mississippi Valley and Great Lakes regions it is characterized by striking predominance of type B. Similarly prevalent is the latter type in the Atlantic States, Maryland, Delaware, New Jersey, North and South Carolina, while scattered findings of type A in Maine, New York and Pennsylvania indicate the existence of breeding places in



virgin forests of the mountains. Soil which is subjected to intensive cultivation and fertilization contains as a rule *C. botulinus*, type B.

**Thermal Death Point of the Spore.** To safeguard against botulism in canned foods, a series of thermal death points of the spore were determined by Weiss (1921). The various factors, such as age of the spore, number of spores, strain differences, hydrogen ion concentration, effect of desiccation, etc., which influenced the thermal death point were also determined.

Weiss found that, suspended in water, the most resistant types require five hours at boiling temperature, 40 minutes at 105° C, 15 minutes at 110° C, and 6 minutes at 120° C. These represent bath temperatures and include the time necessary to heat the spore itself to the temperature stated. Weiss further found that young spores are more resistant than old spores; that dry spores are much harder to kill than moist spores; and that acids, alkalis and various chemicals greatly diminish the thermal resistance.

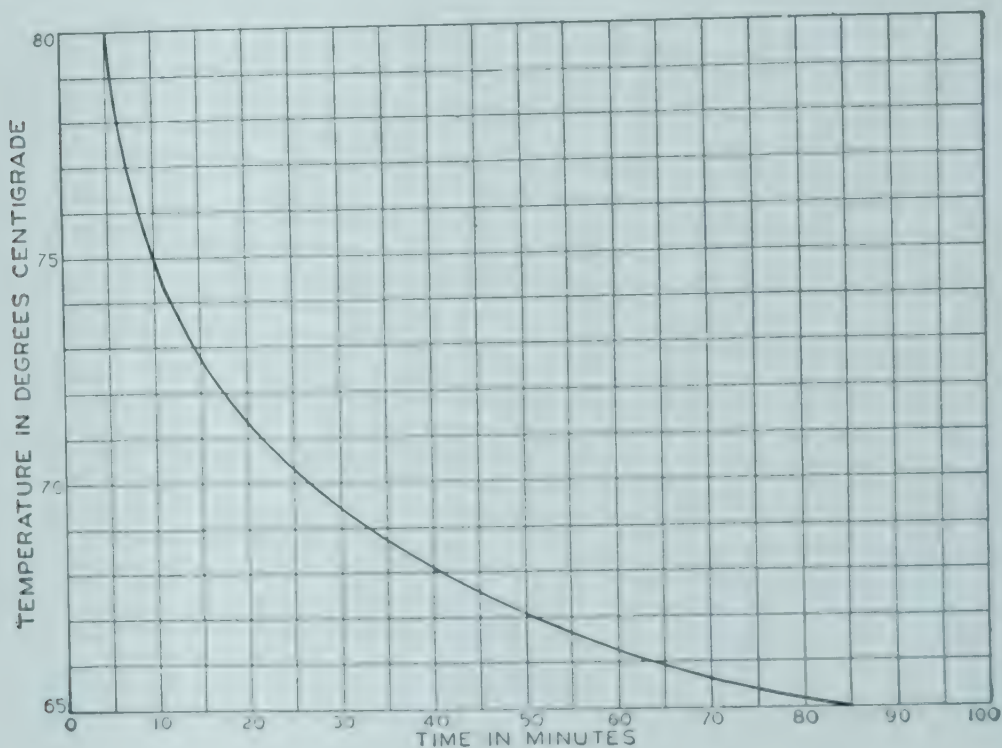


Fig. 21-2. Curve 2, showing rate of destruction of botulinus toxin.

The time and temperature necessary to kill the spores varies with each food product, its pH, bulk, physical and other characteristics (Meyer, 1931). Es (1923) suggested time temperature relationships for completely destroying spores of *C. botulinum* as follows: 100° C, 360 minutes; 105° C, 120 minutes; 110° C, 36 minutes; 115° C, 12 minutes; 120° C, 4 minutes.

**Toxin.** The bacillus produces a soluble, true exotoxin comparable in all respects to the poisons produced in cultures of diphtheria or tetanus. The botulinus toxin is the only one of the true toxins that is poisonous when taken by the mouth. It is also pathogenic for guinea pigs, mice and monkeys, as well as for man. One or two drops of a culture placed upon a piece of bread causes death in a few days. Toxins of diphtheria and tetanus are not poisonous when taken by the mouth.

The toxin is secreted by the bacillus when it grows upon a suitable medium, under anaerobic conditions. Some strains do not produce toxin, and the property may be lost after prolonged artificial cultivation. Toxin production takes place between  $20^{\circ}$  and  $30^{\circ}$  C, but best at  $37^{\circ}$  C, contrary to our previous conception. It was stated that the toxin is always preformed in foodstuffs, but the work of Orr (1919) showed that guinea pigs and mice may develop botulism when fed enormous quantities of toxin-free spores. The significance of this observation to human botulism must await further study.

Botulinus toxin is not absorbed through the unbroken skin, but Geiger (1924) has shown that the possibility of absorption through fresh wounds or from mucous surfaces must be taken into account.

Botulinus toxin is exceedingly poisonous. It has been possible to obtain a toxin of which 0.000001 ml. would kill a 250-gm. guinea pig in from three to four days. In the Ellezelles outbreak in 1897, about 200 gm. of the poisonous ham were sufficient to cause the death of one of the patients; in the Darmstadt outbreak in 1897, a piece of preserved duck the size of a walnut was sufficient to cause an illness which lasted for eight weeks. In Dickson's series of cases, one patient died after "nibbling" a portion of a pod of the spoiled string beans, one died after tasting a small spoonful of the spoiled corn, and a third was ill after tasting a pod of beans which she did not swallow.

Strong toxin was produced by Dickson in pork and beef infusion, and also in media prepared from string beans and green corn; much less virulent toxins were obtained in media prepared from asparagus, artichokes, apricots, and crushed apricot stones. The most powerful poisons are produced in glucose broth. The toxin is not formed in brine containing over 8 per cent of sodium chloride or in syrup containing over 50 per cent of sugar. This is of practical importance in pickling and preserving foods.

In 1897 van Ermengem showed that the toxin was destroyed by heating at  $80^{\circ}$  C for one-half hour, and many later workers have verified this, showing in fact that there is a margin of safety in such a procedure. Thom and others (1919) showed that the toxin of the Boisé strain is destroyed at some point between  $70^{\circ}$  C and  $73^{\circ}$  C by heating for 10 minutes. Orr (1920-2) showed that the most resistant of the 10 strains of toxin studied by him is destroyed when exposed to  $80^{\circ}$  C for two minutes,  $72^{\circ}$  C for 10 minutes, and  $65^{\circ}$  C for 85 minutes. The toxins of most strains are killed at  $65^{\circ}$  C in 30 minutes. Cooking, therefore, is a safeguard. The toxin in solution is very resistant to exposure to light and air. It is not affected by drying or putrefaction. The toxin of *C. botulinum*, type A has been obtained in crystalline form by different groups of workers (Abrams and others, 1946; Lamanna and others, 1946). It has, therefore, been possible to study the physical and chemical characteristics and toxic properties with great precision.

The toxin has a special affinity for the central nervous system; it is almost a pure neurotoxin. It may also cause dilatation of the blood vessels, thrombi and hemorrhages in various portions of the body.

van Ermengem found that white mice, guinea pigs, rabbits, cats, pigeons and monkeys are susceptible to subcutaneous, intraperitoneal and intravenous injection, and that white rats, dogs, chickens, frogs and fish are highly resistant. In his feeding experiments, he found that mice, guinea pigs and monkeys are especially susceptible,



rabbits are less susceptible, and cats must be given enormous quantities of the toxin before they show symptoms. He found that dogs, rats and chickens are practically unaffected, the only result of feeding large doses being vomiting, diarrhea and emaciation. It is surprising that van Ermengem failed to obtain positive results in his experiments with dogs and chickens, for chickens may be used as test animals to determine the presence of the toxin in food. Horses, goats and other animals are susceptible.

**Antitoxin.** A true antitoxin may be obtained by injecting increasing amounts of the toxin into susceptible animals. Kempner first obtained the antitoxin in goats. It is now made by injecting horses. The botulinus antitoxin has both protective and curative virtues in experimental animals, even when given 24 hours after the ingestion of the poison, but before the onset of symptoms. For practical purposes at least two antitoxins must be on hand, one made by strain A, and the other by strain B. The presence and type of toxin in food can be determined in a few hours by injecting mice intraperitoneally. Some of the mice should be immunized with antitoxin type A and some with type B.

**Toxoid.** Nigg and others (1947) have prepared toxoids from botulinus toxins type A and B. Tested in guinea pigs and mice they have been found to produce a high level of antitoxic immunity. Both the fluid and alum-precipitated botulinum toxoids types A and B have been used to immunize man (Reames and others, 1947). It apparently affords protection to laboratory personnel working with these toxins who may be exposed to risk through accidents.

**Food Involved in Botulism.** It was originally thought that *C. botulinum* would grow only in meat, but it is now known that the presence of animal protein is not necessary for its growth. In Europe, the foods involved in outbreaks have been mainly meats, such as sausage and ham, but in this country other foods have been involved, such as string beans, cottage cheese, corn, asparagus salad, peas, spinach and ripe olives. Botulism has also been attributed to turkey, beef, chicken and fish.

Most cases of botulism are caused by food that has received some preliminary treatment, as smoking, canning or pickling, and not by fresh food. Home processed foods have been especially responsible, for the reason that they are often a day or more old when put up, and the temperature of processing is frequently not sufficient to kill the botulinus spores. All the olive cases were due to ripe olives, improperly processed, put up in glass, and insufficiently heated.

van Ermengem found that the outbreak in Ellezelles was caused by eating ham which had been preserved in brine. Smoked as well as pickled ham has been responsible. In Russia fish has conveyed the poison. Madsen also isolated *C. botulinum* from poisonous fish. A most interesting outbreak occurred in Darmstadt in 1904, caused by a salad prepared from home-canned white beans.

Sausages are a frequent source of botulism in Germany. The sausages readily become infected and present ideal anaerobic conditions for the growth of the organism, especially as they are rarely refrigerated and frequently contain old and contaminated scraps. Certain sausages, as, for example, the blood sausage and the liver sausage prepared in Württemberg and Baden, are likely to be toxic. Venison and old roasts have also produced the intoxication. Of 483 outbreaks in the United States and Canada (1899-1949), 361 were due to canned fruits and vegetables.

to meats, 30 to fish and other sea foods, 7 to milk and milk products, and in 48 the causative food was unknown (Meyer and Eddie, 1950).

**Prevention.** The prevention of botulism consists in greater care and cleanliness in the preservation of nitrogenous foodstuffs. The bacillus will grow and produce toxin only in foods containing protein. There is no danger of botulism in fresh food. In all instances, the trouble comes from food that has been canned, preserved, pickled or processed in some way. Home-canned foods are often at fault. It is, therefore, important to teach safe methods of home canning, especially the importance of putting up only fresh and clean food, heated sufficiently to kill the spores— $120^{\circ}\text{C}$  for 10 minutes. This is the minimum temperature and time to kill the naked spores under laboratory conditions. In actual practice a larger factor of safety is necessary in order to provide for penetration of the heat throughout the cans. Canned foods should be processed at a temperature sufficiently high and held there sufficiently long to render the contents of the can sterile, which will include the killing of botulinus spores. Food commercially preserved in the United States has not been connected with any recognized case of botulism since 1925. The canning industry has taken measures to safeguard against the intoxication. Sterile food is safe food. The cans should be tight.

The heat of cooking is sufficient to detoxicate the poison, but does not kill the spore. Food, therefore, that is allowed to stand around after cooking permits bacterial growth. The importance of proper refrigeration to prevent botulism, as well as other bacterial contamination, is evident.

Cooking is a safeguard, but it must be thorough and recent: thorough in order that the heat may penetrate throughout the mass and kill the toxin; and recent in order to prevent the re-formation of the poison. If the food is kept at ordinary temperatures after cooking, botulinus and other organisms may grow and may cause trouble. Toxin may re-form in cooked food allowed to stand 24 hours at room temperature. Home-canned goods or any other processed goods, if doubtful, should be again cooked just before serving. Food preserved in a brine of 8 per cent or greater is safe, for the toxin does not form in salt solution of this concentration. A syrup of at least 50 per cent sucrose has been found necessary to inhibit growth. A hydrogen ion concentration of 4.5 prevents the formation of this poison; therefore, botulism is unknown in acid fruits.

Reliance cannot be placed upon odor, taste or appearance to detect the toxin of botulism in food. It is true that in many instances a history is obtained that the responsible food looked spoiled, tasted wrong or smelled tainted. Experts can detect the peculiar butyric acid smell of cultures of botulinus, but some strains produce little or no odor. A safe rule is not to eat food that is soft, mushy, and shows gas with a spoiled or putrefactive odor. Canned food that shows gas formation or other evidence of spoilage should not be eaten, especially if home processed. A very small amount of the toxin-containing food is sufficient to cause symptoms and death. Merely tasting the contents, or just "nibbling" the food has been fatal.

The occurrence of limberneck in domestic fowl, if it has developed after they have eaten refuse from the kitchen, may be an indication for the prophylactic administration of the botulinus antitoxin to all persons who have eaten the suspected food.

Effective measures have been taken by the State of California (Meyer, 1931) to protect foods against botulism.



When a case of botulism occurs, persons who have eaten the suspected food should receive a prophylactic dose of botulinus antitoxin; both strains A and B should be used. The serum is of little avail after symptoms have begun.

**Chemical Food Poisoning.** The term chemical food poisoning usually refers to inorganic compounds introduced into foods as adulteratives or by carelessness or, occasionally, by maliciousness in sufficient quantities to cause illness. If the dosage is sufficiently large some of these chemicals may give rise to symptoms of acute gastro-enteritis causing confusion with bacterial food poisoning. Such symptoms may occur after ingestion of foods containing adequate amounts of antimony, arsenic, barium carbonate, cadmium, sodium fluoride, lead and mercury. However, the symptoms make their appearance from a few minutes to one to two hours after ingestion of the contaminated food. It is possible, therefore, in most instances where prompt investigation is instituted to obtain some of the suspected food and ascertain the nature of the poison by chemical analysis.

Typical of this type of food poisoning is an outbreak involving a total of 85 British soldiers as reported by Morten (1945). Thirteen men were admitted to a military hospital with acute gastro-enteritis. They had become ill one hour after eating their evening meal, which consisted of meat, vegetables and a marmalade tart. Three sergeants who had not eaten were not affected; five soldiers who had eaten some of the tart but no other part of the meal were affected. Before the results of a chemical analysis of the suspected food were available, 71 men in the same unit were taken ill two hours after a subsequent meal. It consisted of meat, vegetables, and a treacle tart. Only the men who ate the tart were made ill. The chemical analysis of the pastry of the tarts revealed a large quantity of barium carbonate. At the supply depot a sack containing four pounds of barium carbonate for use as a rat poison had been placed in error in the flour store, filled with ordinary flour and issued to the unit.

Much can be done to control accidental food poisoning by eliminating the presence in food handling establishments of poisonous chemicals which may be mistaken for such foods as flour and powdered milk. White sodium fluoride is commonly used to kill roaches in kitchens and food handling rooms; white powdered insecticides containing arsenic are also used. In some states regulations have been passed prohibiting the use in food handling establishments of compounds containing arsenic or fluorine in any form unless such compounds are distinctly marked with blue, green or red to a stated intensity. New York State requires an intensity of not less than value 8 chroma 4 in accordance with Munsell system of color notation. Prevention may be furthered by regulations forbidding the use of silver polish containing cyanide and prohibiting the use of lead, solder containing lead, cadmium, copper or other metals in food contact surfaces of containers or equipment. By the proper enforcement of effective pure food and drug laws and regulations the danger from adulteration and preservation can be greatly reduced.

### ADULTERATION OF FOOD

Adulteration of food consists of a large number of practices, some of which are fraudulent, others technical in nature. Some forms of adulteration are injurious to health, but for the most part they have an economic rather than a sanitary significance. Foods may be adulterated in a variety of ways, by the removal of nutritive

substances; by the addition of injurious substances; by the fraudulent substitution of cheaper articles; by misbranding; or by the sale of food that is filthy, decomposed or putrid.

Prior to the passage of the Pure Food and Drugs Act in 1906 a large percentage of the food sold in the United States was found to be "adulterated" in one way or another. In Massachusetts, the State Board of Health began to examine foods for adulteration in 1883. It was then found that between 60 and 70 per cent of all foods examined were adulterated. As a result of official surveillance the percentages fell in a few years to approximately 15 per cent and have remained between 10 and 20 per cent since. This does not mean that from 10 to 20 per cent of all foods found on the market are adulterated, for samples are collected from suspicious sources, so that the ratio of adulteration of food analyzed in the laboratory is higher than that of the same foods sold on the market. At the agricultural experiment station in Kentucky it was found that 40 per cent of 727 samples were adulterated; in 1899, at the Connecticut Agricultural Experiment Station, 41.5 per cent of 574 samples of spices and over 25 per cent of coffee samples were found to be adulterated. The situation has greatly improved as a result of the pure food laws.

**Kinds of Adulteration.** A food is considered adulterated in accordance with the Food and Drugs Act of June 30, 1906:

1. **MIXING.** "If any substance has been mixed and packed with it so as to reduce or lower or injuriously effect its quality or strength." This is the simplest form of adulteration, and a good example is the addition of water to milk. Cocoa shells are sometimes mixed with cocoa or chocolate. Glucose and caramel are added to maple syrup; talc to flour.

2. **SUBSTITUTION.** "If any substance has been substituted wholly or in part for the article." As illustrations we have the substitution of cottonseed oil or corn oil for olive oil; glucose or saccharin for sugar; cereals, which cost much less than meat, in sausage. Apple cores and parings are frequently used as a substitute for currants and other fruits in jellies.

Saccharin, or orthobenzosulphamid ( $C_6H_4.CO.SO_2.C_6H_4$ ), is made from toluene. It is several hundred times sweeter than sugar and comparatively cheap. It has, therefore, been used as a substitute for sugar as a sweetening agent in the inferior qualities of ginger ale and other soft drinks, and to some extent in canned corn, peas, etc., as well as in candies and other articles. Saccharin is a chemical obtained from coal tar and is without food value; it is not entirely harmless. The Referee Board reports that "the continued use of saccharin for a long time in quantities over 0.3 of a gram per day is liable to impair digestion; and the addition of saccharin as a substitute for cane sugar reduces the food value of the sweetened product and hence lowers its quality." Saccharin-containing foods are therefore regarded as adulterated within the meaning of the Food and Drugs Act. The substitution of cheap chemicals for high-priced natural flavoring extracts, the substitution of acetic acid or even mineral acids for genuine vinegar, the paraffin polishing of rice, and similar devices are nothing but common frauds, which may in some cases also be injurious to health.

3. **ABSTRACTION OF VALUABLE CONSTITUENTS.** "If any valuable constituent of the article has been wholly or in part abstracted." Skimming milk is a good illustration of this part of the law, or the abstraction of cocoa butter from chocolate. There is, however, no objection to abstracting valuable or nutritive substances provided



the label properly announces the facts; thus, skimmed milk or cocoa are legitimate foods. So also the caffeine may be taken out of coffee and the product sold as caffeine-free coffee. The essential oils are sometimes extracted from cloves or other spices, which are subsequently ground and used as an adulterant with unextracted spice. Abstraction without honest labeling is a fraudulent practice.

4. CONCEALING INFERIORITY. "If it is mixed, colored, powdered, coated, or stained in any manner whereby damage or inferiority is concealed." This is a frequent form of adulteration, and, as a rule, is undesirable and sometimes injurious. The artificial coloration and decoloration of foods has reached the point of being a fine art. Substances used to color foods are usually considered in four classes: (1) mineral dyes, (2) vegetable dyes, (3) aniline or coal-tar dyes, (4) ethylene for ripening and coloring. The principal *mineral dyes* are: copper sulphate, oxide of iron and potassium nitrate. Copper sulphate is used to give a green color to peas, pickles and similar foods. The copper probably unites with the albuminous matter to form new compounds which have a bright green, sickly color. The oxide of iron and also sulphites are used to redden meats; potassium nitrate will also give a bright red color to pickled or corned meat. Many *vegetable dyes* are used, such as annatto (the juice of the *Bixa orellana*, a South American tree), which is used to color butter. Carrot juice is also used; turmeric in mustard; and logwood in wines. The *coal-tar dyes* have largely replaced the vegetable and mineral pigments in foods, on account of their brilliant color and cheapness. They are used in sausages, confectionery, jellies and jams, meats, flavoring extracts, etc. The permitted dyes are harmless to health. Citrus and other fruits, tomatoes, etc., are artificially ripened and colored with ethylene. This practice has grown tremendously.

The artificial coloring of food is a false standard and serves no useful purpose. When the coloring is done to conceal damage or inferiority the practice is indefensible, as when spoiled meats are made to look bright red and fresh, or when oleomargarine is colored in order to imitate butter and sold as such. Flour may be bleached with nitrogen peroxide. The flour absorbs this poisonous gas as a sponge absorbs water and instantly becomes white. Processes of this kind should be regarded as a common fraud, for the flour is not improved in any way except in appearance, which is, after all, a deception. The City of New York requires flour that has been bleached with oxide of nitrogen, or nitrous oxide or nitrates, or chlorine to be legibly and conspicuously labeled "Bleached with ————." Dried fruits are bleached by exposure to sulphur fumes, which leaves objectionable sulphur compounds. Candies and chocolate are coated with gum benzoin or shellac. Concealing inferiority may be both an economic fraud and a health menace.

5. ADDITION OF POISONS. "If it contains any poisonous or other added deleterious ingredient which may render such article injurious to health." This section of the law is intended to include adulterants, such as formaldehyde, sulphites, arsenic, hydrofluoric acid, lead, salicylic acid, borax and boric acid, as well as any other injurious substance. Most of the storm center of the opposition to the Pure Food Law centered around this paragraph, owing to the difficulty of deciding in certain instances whether small amounts of benzoic acid or benzoates, boric acid or borates are injurious to health or not.

6. DECOMPOSITION. "If it consists in whole or in part of a filthy, decomposed or putrid animal or vegetable substance or any portion of an animal unfit for food."

whether manufactured or not, or if it is the product of a diseased animal or one that has died otherwise than by slaughter." Examples: oysters, contaminated with sewage; eggs known as "rots and spots"; animals which have died from disease or by accident; figs containing an excessive quantity of worms and worm excrement. This paragraph of the law has caused much discussion, especially the meaning of the word "decomposed."

7. MISBRANDING. The term "misbranding" is specifically defined in the Pure Food and Drugs Act and provides for all possible conditions of fraud, mislabeling, imitation, substitution and other forms of deception. Misbranding is regarded as a form of adulteration under the provisions of the Pure Food and Drugs Act.

Misbranding practices under any circumstances are so evidently fraudulent or dishonest that they cannot be justified on any score and are wholly condemned. It is true that many instances of misbranding do not directly affect health, except in so far as they deceive the consumer; that is, he is purchasing at a high price an article which contains less nutritive value than claimed for it. An honest label which correctly states the character, origin, amount, and the constituent parts of an article is as much a desideratum in food products as it is in commercial articles of all kinds. Honest labeling is the heart and soul of the pure food movement.

## PRESERVATION OF FOODS

The preservation of meat, vegetables and other perishable foods is one of the important questions we have to deal with in hygiene. The proper preservation of foodstuffs involves not only the art of keeping them "fresh" and wholesome, but also keeping them so that they will not lose their nutritive value. Finally, foodstuffs must be preserved so that they will not acquire injurious properties. The preservatives ordinarily in use are: cold, drying, salting, smoking, canning, preserving, chemical treatment, fermentation and physical processes. The preservation of food by cold, or sterilization by heat have the advantage over other processes in that they cause comparatively little alteration in the food.

Practically all these methods have long been in use. The only modern innovations in the preservation of foods are the perfection of the old processes, and the use of mechanical means, such as vacuum, filtration, pressure, radiation, etc. Heat and cold represent old family methods which have been extended and improved in the modern canning and cold storage industries. The drying of fruits, fish and meats is a practice of very ancient origin. The use of salt doubtless antedates all historical records. Sugar either alone or with acetic acid in the form of vinegar and with various spices is an old contrivance and well known everywhere. The application of creosote obtained crudely from the smoke of incompletely burned wood is the ancient forerunner of some of the modern packing processes. Fermentation to preserve food is one of the oldest of the arts.

Concerning the value and legitimacy of these old family methods there is comparatively little difference of opinion; salt meat is not as good as the fresh article; dried apples do not make the best apple pie; chipped beef is not an adequate substitute for a fresh steak. However, it is absolutely necessary to preserve food in some way in order to tide over the winter or the dry seasons, to furnish food to people living and working in desert and arid regions, and to feed the hordes of people



massed together in great cities. It would be impossible to maintain the large population of a modern metropolis if it were dependent upon a daily supply of fresh food materials.

The art of preserving foods successfully is largely a problem in applied bacteriology. It is now possible to keep most foods for long periods without materially injuring their nutritive value or seriously interfering with their appearance and taste.

The chief mischief was the threat of a blind use of chemical germicides without regard for their effect upon health. The simplest and cheapest way to preserve food is by adding one of these chemicals, and the method was, therefore, seized upon by alert men whose chief interest was of the pecuniary kind. The question was to find the smallest percentage of a chemical which would prevent the decay of some particular food product, trusting to luck that the preservative used might prove harmless to the consumer. Often these chemicals were added with a liberal hand and the abuse grew; further, it was soon found that chemicals could be used to preserve food products for the market from material already so decayed as to be unsalable in their original condition, and the unscrupulous profited thereby.

The National Pure Food and Drugs Act \* of 1906 was passed largely to meet this situation. This law considers any food which contains "any added poisonous or other deleterious ingredient which may render such article injurious to health" as adulterated. To Harvey W. Wiley belongs the credit of inducing Congress to pass this legislation against opposition and for an aggressive administration that proved useful in bringing the whole question prominently before the public.

**Refrigeration.** Cold prevents or hinders bacterial activity. Low temperatures in themselves do not kill bacteria, but prevent the growth and multiplication of most of them. In other words, cold is bacteriostatic rather than germicidal. The effect varies with the temperature. Many plants and even frogs may survive freezing; in fact, some molds will grow at the freezing point. Furthermore, cold delays or checks the action of enzymes, which cause ripening. Little change occurs in chemical, enzymic or nutritive properties in freezing. The rate of chemical and biological activity is a function of temperature. Changes are largely physical. Frozen food should be consumed as such or within a few hours after defrosting.

Burdon-Sanderson, in 1871, was the first to show that freezing does not kill bacteria. Von Frisch demonstrated that subjecting a putrefying solution to a temperature of  $-87^{\circ}\text{C}$  for some hours did not effect sterilization. Leidy, in 1848, showed that water derived from melted ice contained not only living infusoria, but also rotifers and worms. Pictet and Young found that anthrax and symptomatic anthrax cultures were not killed after an exposure of 108 hours to  $-70^{\circ}\text{C}$ . Later Macfayder proved that the temperature of liquid air does not kill bacteria; he subjected culture to a temperature of  $-315^{\circ}\text{F}$ . Ehrlich has shown that cancer cells kept cold will live and remain virulent for at least two years.

While no micro-organism pathogenic for man will grow and multiply at the low temperatures of the refrigerator, there are a number of saprophytic bacteria and molds that develop abundantly at temperatures as low as  $0^{\circ}\text{C}$ . Milk, meat, egg and other products kept in cold storage, but below the freezing point, may show a notable increase in the number of bacteria. In the case of milk these low temperature micro-organisms belong mainly to the putrefying and proteolytic group. The

\* Now known as Federal Food, Drug and Cosmetic Act, 1938.

produce an alkaline reaction in the milk and a bitter taste. There is no evidence that poisonous products are formed under these conditions.

For the most part pathogenic bacteria withstand freezing temperatures. They, however, suffer a quantitative reduction when frozen. The element of time here plays an important role, as most of the frailer pathogenic bacteria eventually die. In the ripening of cheese where bacteria cultures are used, pathogens such as *Salmonella typhosa* (*E. typhosus*) gradually die off, possibly as the result of end products of the culturing organisms. When cheese is made from raw milk naturally infected with *S. typhosa*, experience has shown that the cheese after storage for 60 days or more does not cause typhoid fever in persons who eat it, although it would cause disease if eaten a week or two after manufacture. From a sanitary standpoint the protection afforded by refrigeration is partial; it cannot be depended upon to disinfect. In fact, it acts as a good preservative for some viruses.

Some *animal parasites* die in cold storage; some, however, survive. Thus, *Trichinae* die at or below 5° F in less than 20 days (see trichinosis, page 891). If the temperature is maintained at 15° F or below, the larvae of *Taenia saginata* (the beef tapeworm) are killed within six days, but this cannot be depended upon for *T. solium* (the pork tapeworm). Rabbits refrigerated may not be safe so far as tularemia is concerned.

**TEMPERATURE OF REFRIGERATION.** The best temperature at which foodstuffs may be kept must be determined in each case. Some substances, such as meat and poultry, are better preserved when actually frozen; others, such as shellfish, eggs, milk, potatoes, oranges, etc., are materially injured by freezing. For temporary preservation fish are kept at refrigerator temperatures. If preserved in cold storage, they may be frozen, then dipped in water and refrozen in order completely to encase them in ice. They are then stored at a temperature of -16° C. The coating of ice, which is renewed as occasion requires, prevents loss of water due to surface evaporation. Under these circumstances fish may be preserved two years without appreciable change in appearance, flavor or nutritive value.

**HOUSEHOLD ICEBOX.** In any event, the temperature of the icebox should not rise above 7° C. At this temperature bacterial growth does not entirely cease, although very markedly hindered. The temperature of modern mechanical refrigeration can be set and controlled. Few household refrigerators depending on ice maintain a satisfactory low temperature. A study of such iceboxes disclosed the fact that the temperature is often 15° C and higher. Such conditions make good incubators, favoring bacterial growth. *S. enteriditis* will grow at 10° C. The necessity for scrupulous cleanliness, aeration and dryness in all refrigerating devices needs only be mentioned.

**COLD STORAGE.** There has been a phenomenal growth in the frozen food industry in the past few years. For example, there was a production in the United States in 1930 of 320,000,000 gallons of ice cream, 77,000,000 pounds of poultry, 30,000,000 pounds of strawberries, 100,000,000 pounds of fish, and correspondingly huge quantities of meats, fruits, vegetables and other frozen products.

In ordinary refrigerating plants moisture condenses on the surface of the objects exposed. In the case of meat this moisture dissolves some of the proteins, extractives and salts, and makes a perfect culture medium for bacteria and molds. It is, therefore, better to hang meats in a current of dry, clean air, in order to desiccate the



surface, before they are placed in the refrigerator. The dried surface delays the inward growth of the inevitable bacterial contamination upon the surface.

Articles of food may be kept in a satisfactory condition in cold storage for a long time. The time varies with the article and its condition when placed in storage, also with the temperature and other factors. A striking illustration of the great preserving power of low temperatures occurred some time ago in northern Siberia. In consequence of a great landslide on the banks of the Kolyma, the head of a mammoth became exposed and was so well preserved that even the fleshy trunk remained. It is said that famished wolves and half-starved natives began to eat of the flesh. The Russian government sent Hertz to rescue what remained. The mammoth had remained in cold storage perhaps thousands of years. Some of the soft parts were sent to the Museum at Leningrad. This must not be taken as justification of prolonged storage or the "cornering" of foods for economic gain in mammoth cold storage warehouses. While meat, poultry, eggs and vegetables may be kept in a satisfactory condition for months and transported over seas, cold storage should not be unduly prolonged. In any case, the consumer is entitled to know whether the article is fresh or stored, and the time it has been in cold storage. These facts should be stated upon the label or stamp.

The question of cold storage poultry was investigated by the Massachusetts State Board of Health, and the conclusion was reached that it made practically no difference whether the fowl were drawn or not, but that they must be perfectly fresh when placed in cold storage. Poultry kept below 0° C shows little or very slow change. It was found that cold storage fowl are even less contaminated with bacteria than freshly killed birds that have hung for a few days. However, the cold storage foods, when removed from the refrigerator, decompose more quickly than the fresh.

Contrary to what might be expected, drawn poultry decomposes more rapidly after removal from cold storage than undrawn. This is because in the process of drawing, the intestines are broken and the carcass is exposed to intestinal and other bacteria. If the entire alimentary canal, esophagus, crop, gizzard and intestines are removed intact, and with bacteriologic care to prevent contamination, the bird is practically safe from putrefaction.

The deterioration of foods held in cold storage is slow but nevertheless real when measured in terms of months or years. Storage temperatures may vary from 31° to 40° F for such products as meats, fruits, vegetables, milk, cheese and eggs, and 0° F for frozen foods. In general, lower temperatures permit longer storage without bad effects. Some foods cannot be frozen without damage. The principal deleterious effects of long storage are desiccation, discoloration and loss of texture and flavor. There is no definite evidence of any deterioration that may affect health directly. It has been demonstrated that at fixed temperature some foods may be held much longer than others without serious effect on quality. Cold storage for short periods may even improve quality, as in storing freshly slaughtered meat for tenderizing. It is believed that the action of enzymes at low temperatures is responsible for much of the change in foods in storage.

Many states have enacted laws and regulations governing the operation of cold storage warehouses. Enforcement generally rests with the state health department, the state department of agriculture, or a dairy and food, or food and drug commission. Regulations are designed to require the maintenance of low temperatures, to

permit inspection and access to records, to prevent holding foods for unreasonable periods of time, and to require labeling as cold storage products.

**FROZEN FOODS.** With the development of the quick freezing method resulting in little structural damage to foods so processed, this method of preservation is becoming popular both with respect to foods commercially packaged and frozen to those packaged and frozen at home in so-called "deep freeze" units. A few studies have been made of the total bacterial counts of commercially frozen foods. The counts on some of the prepared creamed foods are rather high. However, there is no present indication that the bacteria present have caused illnesses (see salmonellosis, page 208). Studies show that methods of handling frozen foods in transit are not ideal and that at times the temperature within the package instead of being at  $0^{\circ}\text{F}$  may be above the freezing point, as indicated by the melting of incorporated ice cubes. Inadequately refrigerated freight cars, long hauls on poorly insulated trucks, and exposure on platforms while loading or unloading are all factors. Mechanically refrigerated freight cars that will hold packaged goods at well below  $0^{\circ}\text{F}$  while in transit are in experimental use. The general substitution of such cars for the present refrigerator cars with ice bunkers should be helpful in improving the quality of frozen foods subject to long hauls.

The development of locker plants for frozen foods has created problems. Any failure to maintain foods continuously in a frozen state may cause spoilage with possible danger to health. Because of the money value of foods in storage it is likely that the operator will try to conceal temporary lapses by refreezing the foods in which toxins may have developed while the foods were warm. It has been recommended by the Committee on Sanitary Engineering and Environment of the National Research Council that official regulations covering locker plants include the approval by the state health authority of plans for new plants to insure the maintenance of adequately low temperatures and prevent nuisances; that special attention be given to securing sufficient and reliable insulation of floors, walls and ceilings of storage rooms; that duplicate compressors be provided; that wherever possible standby electric service be provided, and that to avoid nuisances or health hazards efforts be made to anticipate future requirements for services such as slaughtering animals, meat and food processing and baking.

**SUMMARY.** From a sanitary standpoint, then, refrigeration is one of the best methods of preserving foodstuffs. The advantages of cold as a preservative are that it neither adds any constituent to the food nor takes away any constituent from the food. Cold imparts no new taste, nor does it seriously alter the natural flavor. It does not diminish its digestibility nor cause a loss of nutritive value. It has slight if any effect on most of the vitamins. The material is left in approximately its original condition. Many bacteria will live but not multiply. Cold may, therefore, be regarded as one of the simplest and best antiseptics we have for the preservation of foods. It is now almost universally applied to prevent decomposition and decay. The farmer uses it to keep food in cold cellars, deep wells and the like. Its value and usefulness have been enhanced by the introduction of quick freezing methods with storage at  $0^{\circ}\text{F}$ . The use of mechanical refrigeration in many ways in the preservation and marketing of food is on the increase. Fresh and wholesome food may now be transported to and from the tropics, and the sustenance of large communities in



insular and arid regions is made possible and pleasurable through the preserving use of cold.

**Drying.** Drying, desiccation or evaporation is a favorite and primitive method of preserving meats, and in recent years it has been extended to include vegetables, milk, eggs, and almost every kind of watery food. Dryness furnishes ideal antiseptic conditions. Micro-organisms must have moisture to grow and multiply. Most pathogenic bacteria soon die when dried, hence the process has a decided sanitary advantage. Furthermore, dried fruits, vegetables or meats are rarely eaten raw, and the cooking is a further sanitary safeguard.

Drying has two principal advantages which simplify the problem of handling and distribution: it improves the keeping qualities of the food and it reduces the weight and bulk.

The effectiveness of drying as a food preservative depends upon the thoroughness with which the process is carried out. It is not so well adapted to meats as to vegetables and fruits. Dried meats lose their natural flavor, which may be replaced with others less real. The keeping qualities of dried food depend upon the degree of dehydration.

**EFFECT ON VITAMINS.** Drying has little or no influence upon some of the vitamins. It certainly does not diminish the activity of vitamin B which protects against beriberi. Dried leaves, such as celery tops and alfalfa, are still good sources of vitamin A, even when dried in the sun, or by artificial heat in a current of air after preliminary treatment with steam. Dried milk is also an efficient source of vitamin A. Drying affects chiefly vitamin C. A diet of dried foods has long been associated with scurvy. Even Captain Cook knew that this deficiency disease could be prevented by the use of fresh food. Milk may be dried so that it contains about one-half its original antiscorbutic property.

**CHANGES IN DRIED FOODS.** The changes which take place in dried foods are more than simple loss of water. There may be physical changes which are not reversible. Some of the constituents become insoluble. Enzymes and oxidation continue their activity, although slowly. Milk and eggs under ordinary conditions of desiccation in time turn rancid.

**METHODS.** The methods of drying have been greatly improved and widely extended. The old-fashioned sun drying has been replaced by vacuum drying. In the tunnel method, the food is placed on racks in tunnels or chambers through which the current of heated air is passed. In the kiln method, the food is placed on the perforated floor and heated from below by means of a furnace. Each food must be processed by a method best suited to its peculiarities. Birdseye describes a process he called dehydration. The basic principle is the very rapid removal of moisture from the food, as a result of which he claims that the food upon reconstitution with water much more nearly resembles the original food than if it were dried by the slower methods in common use.

**DRIED MEAT.** The successful drying of meat requires a suitable temperature and the absence of air. The temperature must be kept below the point where the proteins coagulate and the fats melt. If the drying is too slow, the meat will spoil in the process; if too rapid, a hard protecting layer forms on the surface. Meat is therefore best dried in a vacuum in cut pieces at a suitable temperature. Dehydration by the vacuum method is, in fact, generally applicable to many different foods.

In the dry climates of South America and on our western plains, meat is cut into thin strips, suspended in the air, and exposed to direct sunlight. In a short time the moisture disappears and the hard, dry pieces keep indefinitely, or as long as they are kept dry. The meat retains a fair degree of palatability and practically all of its nutrient properties. This is known as jerked beef.

Dried beef is also prepared by first treating the meat with condiments and then drying it artificially. Chipped beef or dried beef is prepared in this manner, except that the meats are often smoked as well as salted and desiccated, so that in their preparation more than one method of preservation is employed.

Powdered meats are prepared by complete desiccation, and such products are found upon the market as a finely ground powder. Meat powders are made not alone from fresh meats in their natural state, but are also prepared after more or less artificial digestion.

**DRIED FRUITS.** Dried apples are taken as a type of dried fruits and vegetables. The apples may be dried naturally by cutting them into convenient sizes and exposing them to the action of the sun. This is more a domestic than a commercial industry. When apples are dried by this simple process they darken and become unattractive in appearance, which is due to the oxidizing action of the enzymes when exposed to the air. When properly prepared the dried apple has its moisture content reduced to 24 per cent. Dried apples containing 26 to 27 per cent are apt to ferment.

In order to prevent the darkening of the surface, apples are usually subjected to the fumes of burning sulphur. The sulphur dioxide acts as a bleaching agent and the sulphurous and sulphuric acids retained in the apple act as preservatives. Apples treated with sulphur fumes are less likely to decay or become infected with molds than a similar product not exposed to sulphur fumes. The process is objected to from the standpoint of health, for the reason that the sulphurous acids and sulphites are admittedly injurious. The United States Department of Agriculture found that approximately half of the evaporated fruits purchased on the open market had been treated with sulphur fumes. In order to obtain a satisfactory dried product it is of some importance that the fruits be selected so as to reject all imperfect, rotten or infected specimens.

*Evaporated apples* is a term applied to apples dried artificially instead of being exposed to the sun's heat. The process is rapid and satisfactory, and has no sanitary objections.

**DRIED MILK.** Milk must be dried quickly in order that it will not spoil during the process, and the temperature must not be high enough to coagulate the lactalbumin, otherwise the addition of water would not restore the milk to its former homogeneous state. Milk may be dried in a thin film on heated and revolving metal drums or on belts in a current of dry, warm air; or *in vacuo*. In this way the milk can be reduced to a dry state in a short time and without reaching a temperature sufficiently high to materially alter its quality. A favorite method of drying milk consists in atomizing it under pressure and projecting it into a warm chamber, the temperature of which is so regulated that the fine particles are completely deprived of their water before they reach the bottom of the cabinet. The milk is thus reduced almost at once to a fine powder.

Milk that has been dried and is then mixed with water is practically restored to its original condition, except that the solubility of some of the constituents is inter-



ferred with. It is difficult to preserve milk powder against rancidity. It keeps well if it contains less than 2.5 per cent water, but even then the results may be disappointing in handling whole milk.

North reports upon a process for packaging butter oil in tins under nitrogen which he claims will keep without refrigeration for two years or more. A special carefully prepared skimmed milk powder when canned also may be similarly kept. By combining butter oil and skimmed milk powder with water without special equipment but following directions, he claims that a reconstituted milk can be easily prepared that has an acceptable flavor and good food properties.

Dried milk should, of course, be made from milk derived from healthy cows handled under sanitary conditions and free from infection. The milk should be pasteurized before it is reduced to a powder. Powdered milk is finding an increasing and legitimate field of usefulness for cooking, household purposes, as a beverage for adults and even for infant feeding.

Dried milk seems to retain all the essential qualities of the fresh product, except that it has lost some of its antiscorbutic property, and is less attractive. Since practically 88 per cent of milk is water, there is a decided gain so far as handling, transportation and keeping are concerned. For partially dried milk, such as condensed and evaporated products, see section on Milk.

**DRIED EGGS.** Eggs are broken out, mixed and dried by spreading the mass in a thin film on a revolving drum, or by the spray method, similar to that of drying milk. Egg powder keeps well and retains practically all the nutritive value of the original egg. The presence of bacteria in dried eggs is to be expected in view of the frequency with which bacteria are found in the yolks of fresh eggs and the good possibilities for bacteria on the shells to find their way into the egg mass during the cracking process. With the limit set on total bacteria count on dried eggs for the use of the armed forces in World War II, processors experimented with some success with washing eggs prior to cracking and with mild heat treatment.

**Salting and Pickling.** The preservation of meat with brine or common salt is one of the oldest processes known. The brine should contain from 18 to 25 per cent of salt. For red meats a little potassium nitrate is often added; this salt has slight antiseptic properties, but brings out the red color. Haldane has shown that nitrite is formed from the nitrate, and that some nitrous oxide hemoglobin is formed, which gives a bright red color to the meat. In the process of salting, some of the meat protein, bases, and extractives are dissolved out and the fibers become hardened; the nutritive value and digestibility, therefore, are somewhat diminished. The brine should never be less than 8 per cent, for *C. botulinum* will not grow and produce its toxin in this concentration.

The preserving action of salt depends largely upon dehydration, but also upon the direct effect of the chlorine ion, removal of oxygen, and on interference with rapid action of proteolytic enzymes.

Pickling includes preservation of food in brine, vinegar, weak acids and the like. These substances have bacteriostatic and also feeble germicidal properties, depending upon their concentration.

*Pickled meats* are prepared by soaking meat, especially pork, in a brine made of common salt, though other substances, such as sugar, vinegar and spices, are often added. Sulphite of soda, boric acid, borax and benzoic acid, and other chemical

preservatives formerly used are no longer permitted by the United States Bureau of Animal Industry (see page 887). With proper methods chemical antiseptics are not necessary. The vinegar which is employed, or acetic acid, may be injected into the carcass before it is cut up. When the arteries are filled with vinegar in this way it rapidly permeates to all parts of the meat and acts as an excellent and unobjectionable preservative in cases where an acid taste is desired. It is stated that carcasses which have been injected with vinegar are easily preserved and require far less salt and other condimental substances than when not so treated. The process has no sanitary objections.

*Trichinae* die after prolonged periods of pickling. *Cysticerci* die a natural death in 21 days following the death of the host. They are killed promptly in brine, provided the salt comes in direct contact. Owing to the difficulties of penetration, this cannot be depended upon and, therefore, pickled beef from infected cattle is considered free from viable *cysticerci* only after the expiration of three weeks following slaughter. The life of many pathogenic bacteria is shortened in brine, depending upon the concentration and temperature, but the salt must be looked upon as an antiseptic rather than a germicide; that is, it prevents growth rather than kills the bacteria that are present. From a sanitary standpoint there is some, though slight, danger of conveying infection in foods that have been improperly salted or pickled. Attention is called to the fact that the first cases of botulism studied by van Ermengem were caused by ham kept in brine under conditions favoring anaerobic growth. Ripe olives which were responsible for botulism were also treated in brine. In the first instance, the ham stuck partly out of the water, and in the second instance the brine was very weak and dirty, and the heat of preserving insufficient.

**Preserving.** JELLIES AND PRESERVES. By preserving is commonly understood the addition of a large amount of sugar. The principal preserves are jellies, marmalades, jams and fruit butters. These substances are entirely free from the danger of conveying infection, mainly because they are always cooked in preparation. A strong solution of sugar will prevent growth, but cannot be depended upon to kill parasites. However, most pathogens die under such conditions in the course of time. A strong syrup (50 per cent sugar) is necessary to prevent the growth and development of *botulinus* toxin. Jellies and preserves have a comparatively clean bill of health.

Jellies are frequently adulterated by the substitution of apple stock. Apples contain a large number of pectose bodies which favor jellification. Pectose is a carbohydrate similar in composition to cellulose. When boiled with an acid, pectose bodies are hydrolyzed to pectin which takes the jell form on cooling. Pectose bodies which will insure jellification may be purchased on the market.

A common method of manufacturing jelly for the trade has been to use a stock of apple juice or cider, or a preparation made from the cores, skins and rejected portions of the apple at evaporating factories, or from whole rejected apples. This stock is used as a common base for the manufacture of jellies of different kinds. Apple juice used as a substitute for other fruit juices in the making of preserves is a common fraud and an adulteration, according to the Pure Food and Drugs Act, unless plainly stated upon the label. Jellies are also colored artificially, particularly with the coal-tar dyes. Artificial flavors are sometimes employed. The chemical preservatives most frequently added to jellies and preserved fruits are benzoic acid and benzoate of soda. Salicylic acid and others are prohibited.



**Smoking.** The smoking of fish, beef, hams and other food products consists mainly in rapid drying plus the germicidal action of certain substances in the smoke. The meat or fish is exposed to the smoke of a smoldering wood fire of oak, maple or hickory, usually after a preliminary salting. The articles so exposed become dry and impregnated with pyroligneous products—acetic acid and creosote, formaldehyde and other germicidal substances. An artificial or quick method of smoking meat formerly used, but now contrary to law, consisted in brushing the pieces or dipping them in pyrolignic acid at definite intervals, and finally drying them in the air.

The effects of smoking do not go deep—the penetration is only partial; therefore, in sausages of generous diameter putrefaction often occurs in the interior. Smoked sausage may, therefore, be dangerous, as far as various parasites and bacterial injury are concerned, and the same is true of smoked ham and other meats exposed in large pieces. As smoked meats are often eaten raw, the occasional survival of parasites in such products has some sanitary significance.

**Chemical Preservatives.** Chemical preservatives are nothing more nor less than bacteriostatic substances and in the proportions commonly used may have little or no germicidal action. Such substances as sugar, salt, vinegar, vinegar extract of spices, and the pyroligneous products in wood smoke are not regarded as “chemical” preservatives, but as “natural” preservatives or condimental substances, although their mode of action is precisely the same as the chemical preservatives.

There was a great increase in the use of chemical preservatives in foods during the several decades prior to 1906, when the Pure Food and Drug Act went into effect. Chemical preservatives were grasped upon, owing to the fact that this method was cheap, easy and sure. Fortunately, we possess two efficient and wholly unobjectionable processes for the preservation of food, *viz.*, refrigeration and sterilization by heat, which for the most part make it unnecessary to resort to the use of chemical preservatives. One of the most objectionable uses that can be made of chemical preservatives or any other method of food preservation is to conserve foods which are so decayed as to be unfit or possibly injurious to health if used fresh. The law cannot be too strictly enforced in order to prohibit the use of chemical preservatives and condiments used to disguise such foods, which may then be sold at high prices as first quality.

Upon general principles it is undesirable to add a chemical substance of whatever nature to food for the purpose of preserving, coloring, or improving its appearance, and in most countries this practice is prohibited by law. There are, however, a few instances in which the addition of some chemical preservative in minimal amount seems harmless, and occasionally even desirable, as, for example, small quantities of benzoate of soda in catsup; a thin film of gum benzoin as a protective coating for chocolate, etc.

Countries differ widely concerning the use of chemical preservatives in food. No sweeping generalization can be made concerning all chemical preservatives. Each substance must be considered for itself, and each substance must further be considered in relation to the particular foodstuffs for which it is proposed. It may, however, be stated as a general rule that any chemical which is poisonous in large amounts should be considered as poisonous in small amounts until the contrary is proved. In other words, the consumer is entitled to the benefit of the doubt. The

toxicology of various food preservatives is in its infancy and frequently presents a very difficult and complex problem. Thus, lead in one large dose is not particularly harmful. The older practitioners frequently gave 20, 30, and more grains of sugar of lead (acetate of lead) for diarrheal affections. Only a minute portion of the lead taken in one large dose is absorbed; the rest is quickly eliminated. However, if the same amount of lead should be taken in small subdivided daily doses, enough would be absorbed and retained by the tissues so that serious chronic lead intoxication would develop, resulting from the cumulative action. On the other hand, hydrocyanic acid, one of the most poisonous chemicals known, is harmless in small amounts, for the reason that when introduced into the body it meets the available sulphur ( $H_2S$ ), with which it unites to form a sulphocyanide, as  $KSCN$ . The potassium sulphocyanide is not poisonous, and it has been shown experimentally that animals are able to withstand larger quantities of hydrocyanic acid by first giving them substances which increase the available amount of sulphur to form this chemical combination. Benzoic acid in large amounts is irritating and produces well-defined symptoms of poisoning; small amounts of benzoic acid are paired in the liver and eliminated by the kidneys as hippuric acid, a harmless constituent of the urine. Hydrochloric acid and possibly acetic acid and alcohol are all poisonous in large amounts, but they may be regarded as harmless if the amounts taken are sufficiently small. There can be no defense for the use of formaldehyde, salicylic acid, sulphites, and a host of other chemicals. So far as we know, the human organism possesses no natural mechanism for rendering them harmless. There can be no defense for the use of chemical preservatives to hide inferiority.

**BENZOIC ACID AND BENZOATE OF SODA.** These are weak germicides at best, and benzoate of soda in dilutions of 1:1,000 commonly used in food has feeble bacteriostatic power. Benzoic acid is an organic acid contained largely (12 to 20 per cent) in gum benzoin, and also in balsam of Peru and balsam of Tolu. It is obtained from gum benzoin, from the urine of herbivorous animals, and artificially from toluene, by treating it with chlorine and heating with water to  $150^{\circ}C$ .

The reason why benzoic acid in moderate amounts is believed to be harmless is that the body possesses a special mechanism for taking care of this substance. Many of our ordinary foods contain substances which are transformed in the body into benzoic acid. Some foods, such as cranberries, contain this acid in notable amounts. Benzoic acid meets glycocholic acid (one of the decomposition products of protein) in the liver to form hippuric acid. We know, therefore, that the human organism is prepared to take care of and render harmless a certain amount of benzoic acid; we know that this mechanism is efficient and is capable of taking care of relatively large amounts of benzoic acid.

The United States permits the use of benzoate of soda in quantities not exceeding 0.1 per cent in certain foods, but the addition must be plainly stated on the label. There can be no serious objection from the standpoint of health to the addition of these amounts of sodium benzoate to catsup, on account of the small quantity of this article consumed at any one time. Further, on account of the long time a bottle of catsup is usually kept after it is opened in the household, there is, thus, the added economic gain of preserving the catsup until it is all consumed. The same object may be obtained by the use of a sufficiently strong vinegar extract of spices, but the ques-



tion may be asked whether the aromatic and preserving substances in the vinegar extract of spices may not be more irritating than the sodium benzoate.

**BORAX AND BORIC ACID.** Both boric acid and borax are only mild antiseptics. They are generally used together, for the reason that the combination of the two is more efficient than either one alone. Locally boric acid is not very irritating, and for this reason it has been extensively used in surgical practice. To some skins, however, it is irritating, and cases are reported of its absorption from wounds and cavities when used too freely, causing depression and eruptions, such as erythema and urticaria. Fatal results have been reported in a few cases from injecting the solution into abscess sacs, or from washing out the stomach with it; or from taking a large amount by mouth.

Borax and boric acid are not allowed as preservatives in food in the United States and most countries. Canada and France allow them in butter, condensed milk and cream under restriction as to the amount. Formerly, they were extensively used for preserving meats, milk, butter, oysters, clams, fish, sausage and other foods.

The effect of small amounts of boric acid and borax upon healthy human beings has been extensively studied and has resulted in conflicting testimony. These substances are not normal constituents of the body, nor are they normal constituents of foods. Furthermore, there are better methods of conserving food. Therefore the use of borax and boric acid for food preservation should be prohibited.

**FORMALDEHYDE.** Formaldehyde was used extensively as a preservative for milk and occasionally for other articles of food. Concentrated solutions of formaldehyde in large quantities are irritating, and death in isolated instances has been reported from the swallowing of amounts of from 1 to 3 ounces. There has been much discussion as to the effect of the small quantities ordinarily used as a food preservative. Bliss and Novy in 1899 and Halliburton in 1900 have shown conclusively that small quantities of formaldehyde greatly delay the digestion of proteins by the gastric and pancreatic juices, the digestion of starch by the pancreatic juice, and the curdling of milk by rennet. It is also known that some individuals are especially susceptible to the effect of formaldehyde, small quantities in the food causing dyspepsia and other disturbances of digestion. Formaldehyde unites directly with protein matter to form new compounds of an undetermined nature. It hardens tissues, so that it will render fish and meat tough and brittle, even in proportions as dilute as 1:5,000, hence it is not generally applicable as a food preservative. In small amounts it delays decomposition; in large amounts it is an active germicide. Its use in milk was advocated by no less an authority than von Behring, but this view met with almost unanimous protest.

There can be only one opinion concerning the use of formaldehyde in foods, and that is absolute condemnation of the practice. It is prohibited by the statutes of practically all nations having pure food laws.

**SALICYLIC ACID.** Individuals differ greatly in their susceptibility to salicylic acid. In mild cases of poisoning with this substance there is a feeling of fullness in the head with roaring sounds in the ears, dimness of vision, profuse perspiration, confusion and dullness. Large doses of the acid cause intense irritation of the throat and stomach, leading to vomiting and difficulty in swallowing. Later there may be diarrhea. Eczema and other skin eruptions may appear, and dimness of vision and deafness may continue for some time. The long-continued use

salicylic acid and its salts has led to a form of chronic poisoning in which the chief symptoms have been loss of appetite, diarrhea alternating with constipation, irritation of the kidneys, skin eruptions, and mental depression. Such results are said to have followed the use of articles of diet preserved with salicylic acid. The use of such foods may be objectionable in the case of aged, feeble and susceptible persons. Salicylic acid and the salicylates are more efficient antiseptics than boric acid or borax, but they are not used extensively on account of the taste, or rather the tendency to cause unpleasant flavors. They were for the most part used in jams, fruit juices, soda water syrups, cider, wines and other sweet preparations. The objection to the use of salicylic acid in food is practically unanimous and well founded. It is prohibited by the regulations under the pure food act of the United States, and by England, Bulgaria and France, while some countries allow its use in minimal amounts.

**SODIUM NITRATE AND NITRITE.** Sodium nitrate or potassium nitrate (saltpeter) is not used as a preservative, but as an indirect coloring matter. It is reduced to nitrite and thus retains and accentuates the red color of meat. It is not known to be harmful in the small quantities in which it is commonly employed to give a good color to corned and pickled meat products (Grindley & Mitchell, 1917). The Bureau of Animal Industry of the U. S. Department of Agriculture allows nitrates to be used in meat in curing provided the finished product contains not more than 200 p.p.m. Heat used in cooking destroys nitrites but it cannot be depended upon, since the amounts destroyed vary with the degree of heat and the length of cooking. When nitrites are ingested in sufficient quantities they cause a chocolate brown discoloration of the blood by the reduction of hemoglobin to methemoglobin. This condition, known as methemoglobinemia, unless promptly treated may result fatally. Occasional instances of nitrite poisoning are reported. Greenberg and others (1945) report an outbreak in which 11 men were poisoned eating oatmeal in which sodium nitrite was used instead of table salt.

**POTASSIUM PERMANGANATE.** Potassium permanganate is used in the surface of meat to destroy the surface evidence of decomposition. This may be detected by heating a knife in hot water, plunging it into the meat, and withdrawing it quickly, which brings out the hidden odors if putrefactive changes have taken place.

**SODIUM FLUORIDE.** Sodium fluoride has been extensively used as a preservative, antiseptic and insecticide. It has considerable antiseptic power, putrefaction being delayed by the addition of 1 part to 500; and 1 in 200 arrests completely the growth of bacteria. It is highly poisonous to nearly all the lower forms of life, especially to micro-organisms, including algae. It does not coagulate protoplasm but acts as a general protoplasmic poison. For mammals, sodium fluoride is a toxic substance, the fatal dose by the mouth being 0.5 gm. per kilogram of body weight, and subcutaneously 0.15 gm. per kilogram of body weight. The fluorides in administration are deposited in the bones, which usually become white and brittle, and contain crystals of calcium fluoride. It is well to call attention to the fact that fluorine, in small traces, is a normal constituent of bone, teeth, milk, eggs, etc. In large amounts and concentrated, it is directly irritating to the mucous membrane and produces vomiting, diarrhea and abdominal pains. Death of a 10-year-old girl has been caused by the ingestion of one teaspoonful in a little water, given in mistake for Rochelle salts. Baldwin in 1899 reported a number of cases



of sickness and death resulting from the accidental ingestion of sodium fluoride, usually taken in mistake for baking powder. In a classic incident in 1942, in which all 467 of the exposed individuals became sick and 47 died, it is reported that white sodium fluoride, mistaken for powdered milk, was added to eggs in the preparation of scrambled eggs at a state hospital for the insane at Salem, Oregon. Recovery from nonfatal doses is usually rapid and complete. Small quantities ingested daily for a long period of time do not appear to be harmful, but should not be allowed.

Sodium fluoride forms the basis of most roach powders which contain from 16 to 47 per cent of the fluoride finely ground up and intimately mixed with the bait. It is fatal to roaches when so ingested.

**HYDROFLUORIC ACID.** Schultz in 1889 exposed cats for four days to concentrated fumes of hydrofluoric acid without serious effects. The air was so impregnated that glass held at some distance from the source was etched. Hydrofluoric acid is much used for disinfecting vats and tanks in making fermented drinks. It is a powerful germicide.

**SULPHUROUS ACID AND SULPHITES.** Sulphites act as antiseptics and also preserve the red color of meats. Sodium sulphite and bisulphite and sulphurous acid are used principally upon fresh meats, where they act as a preservative and as a retainer of color. Sulphites, even in minute amounts, interfere with the action of ferments, and thus influence digestion. Free sulphurous acid is very irritating. Sodium sulphite is very poisonous when injected subcutaneously or intravenously. Death occurs by paralysis of respiration. Much larger quantities are tolerated by the mouth, the sulphite being slowly absorbed. The greater part is converted to the harmless sulphate during and after absorption. The quantities ordinarily used in preserved food cause no immediate symptoms, even when continued for several months. In 1908, the Imperial Board of Health in Germany forbade the use of sodium sulphite in food on account of its dangerous properties, and it is also forbidden by our Federal Pure Food Act of 1906. On the other hand, sulphurous acid is allowed by more countries than any other preservative.

Sulphur dioxide is much employed for the bleaching of fruits. No objection is made to foods which contain the ordinary quantities of sulphur dioxide, if the fact that such foods have been so prepared is plainly stated upon the label of each package. An abnormal quantity of sulphur dioxide placed in food for the purpose of marketing an excessive moisture content is regarded as fraudulent adulteration under the Food and Drugs Act of June 30, 1906.

**SODIUM BICARBONATE.** Sodium bicarbonate is sometimes added to milk in order to neutralize the excess of acid, and this delays souring. It is too ineffective as a germicide for general use as food preservative.

**HYDROGEN PEROXIDE.** Hydrogen peroxide is perhaps one of the least dangerous of the chemical preservatives, and is considered by some to exert no deleterious effect whatever in the quantities commonly used. It was at one time advocated and used for the preservation of milk and also of wine, beer and fruit juices. It oxidizes and destroys vitamin C.

**ARSENIC.** Arsenic in food comes from a variety of sources. Glucose was found to contain it, especially if impure acid had been used to hydrolyze starch in its production. This was the source of the arsenic in the beer which caused the

demic of peripheral neuritis in 1900 in England. Samples of the glucose contained from 0.01 to 0.1 per cent of arsenic. The finished beer contained from 1 to 3 grains of arsenic per gallon. Arsenic may also contaminate certain aniline dyes as well as shellac which is now so much used as a coating for some kinds of cheap confectionery and baker's goods, and also as a varnish on receptacles and containers of various kinds. Another source of arsenic in food is from insecticide sprays.

In England liquid food is considered adulterated if it contains as much as 0.01 grain of arsenic per gallon, and solid foods are considered deleterious if they contain as much as 0.01 grain per pound.

The use of preservatives containing lead, arsenic or other substances known to be poisonous finds no advocate.

**SPICES.** Hoffman and Evans (1911) have shown that ginger, black pepper and cayenne pepper fail to prevent the growth of micro-organisms. Nutmeg and allspice have slight bacteriostatic properties, but only for a few days. Cinnamon, cloves and mustard, on the other hand, have marked antiseptic powers and are valuable preservatives. The active antiseptic constituents of mustard, cinnamon and cloves are the aromatic or essential oils which they contain.

Recent years have brought a tremendous increase in the use of chemicals in the broad field of food technology. Commercial competition with resultant widespread establishment of control and research laboratories has led to extensive use of chemicals in food by producers, manufacturers and processors.

**Canning.** The process of canning is practically synonymous with sterilization and is, therefore, one of the best sanitary safeguards we have against parasites and bacterial injury in foodstuffs. The process of canning was discovered by the confectioner, M. Appert, of Paris, in 1804 to 1809, long before the days of bacteriology.\* Appert found that meats and other foods in sealed vessels would usually keep indefinitely if, after being sealed, they were kept for an hour in boiling water. He improved the process, in 1810, by introducing a method of sealing the cans after the heating process had driven out the air and replaced it with steam, so that when cool a vacuum is formed. For all practical purposes this is the universal method of canning today.

The time and temperature vary for each food, for the size of the can and technologic technic. Bacteria are killed at definite temperatures in a given time, but the heat must penetrate to the center of the can. It takes longer to heat the contents of a large can than a small can, and penetration is much slower through corn (cream style) or sweet potato than it is through clear soup. The time and temperature for processing each article, therefore, depend on various factors which have been determined, depending on the size of the pressure cooker and the load. The time of processing should be counted from the time when the retort reaches the holding

\* Nicholas Appert, in France, first preserved food in glass jars by sealing them hermetically and heating, in 1804. He published *The Art of Preserving Animal and Vegetable Substances* in 1810. In 1810 Peter Durand obtained a patent in England for preserving fruits, vegetables and fish by hermetically sealing them in tin and glass containers. In 1820 William Underwood and Charles Mitchell, emigrant employees from a canning factory in England, opened a factory in Boston where they canned plums, quinces, cranberries and currants. Glass was used extensively until 1825, when Thomas Kensett secured a patent for use of tin cans and commenced use them in his factory.



temperature. Unless attention is given to these matters, spoilage is inevitable. These same principles apply to home canning. Only fresh and sound fruits and vegetables should be put up.

There is also a mistaken notion that once opened, the contents of the can should be emptied into some other vessel. It is generally believed that food kept in an opened tin can acquires injurious properties. This is a fable, like the souring of milk due to a thunderstorm. On the other hand, canned food may become contaminated or infected after opening, and the same care as to cleanliness and refrigeration is necessary with canned food that has been opened as with any other food in the kitchen.

The process of canning fortunately does not interfere seriously with most vitamins. Its effect varies with the food and the vitamins. It is now well known that most of these "unknown dietary factors" are not destroyed by heat in an acid medium and in the absence of oxygen; practically all our foodstuffs have an acid reaction. The antiscorbutic vitamin (vitamin C) is sensitive to heat and oxidation, especially in an alkaline medium. Vitamin B is also affected in some canned products. It has been shown that it is oxidation rather than heat which affects vitamins, and that when the "accessory factors" are injured it is usually when the food is heated in contact with the air, as in cooking. The pH of the medium is an important factor. The effect of heat on the vitamins is complicated, and the literature is large. It has been collected and tabulated by Kohman in 1919. Hess has shown that canned tomatoes retain their antiscorbutic properties.

Before meats are canned they are first parboiled for 8 to 20 minutes, in order to secure the shrinkage before the meat is placed in the can. In the parboiling there is a certain loss of fat, soluble mineral matter, meat bases and water. However, the shrinkage of the meat concentrates it, as far as nutritive value is concerned and, therefore, compensates for the loss. The parboiled meat is then placed in the tin, a small quantity of the soup liquor added, processed and sealed.

Canned foods are sterile foods; they are the safest foods that come to our table. Canning is synonymous with cooking, and when properly canned, the contents are thoroughly cooked. The process of canning has proved of inestimable benefit to mankind. It enables nourishing food of a perishable character to be kept and transported to great distances and to be used in localities where fresh food are unobtainable. Without this method of preserving foods the pioneer and the explorer would be seriously handicapped. Large army and navy maneuvers would be materially impeded, and great metropolitan cities would be impossible. Wik states that "the winning of the West has been marked by the debris of the rusty can

Canned foods are not only safe, but wholesome and nutritious. The process permits us to have a well-balanced ration throughout the year—irrespective of season. Canning has this further advantage, that the products used must be well ripened; whereas, many fruits and vegetables are picked green and allowed to ripen for the market. The canning industry has grown to enormous proportions and, on account of the great importance of the process, the character and quality of foods thus preserved should be wholly above suspicion, and no adulteration or sophistication of any kind permitted. In the interest of honest and informative labeling, every can should be plainly stamped with the quantity and true nature of its contents. The keeping qualities of canned foods vary with the product

many instances they may be kept two to three years without appreciable change. Some products, for instance loganberries, change in color and flavor. Heat hastens the change and promotes spoilage. All canned products keep better cold.

Spoilage may result from insufficient processing, defective cans or the use of unfit material. These losses are generally classed under the heads of *swells*, *flat sours*, and *leaks*. The ends of a swelled can bulge, and when opened there is evidence of gaseous fermentation and spoilage. "Flat sour" is a term applied to acid decomposition without the formation of gas. "Leaks" are usually due to defective cans, defects in sealing cans, or to corrosion.

If we analyze the different factors responsible for the unsatisfactory results with canned fruits and vegetables, we will find that the most important are: (1) use of unfit raw material; (2) use of unfit cans and glass jars; (3) carelessness in the matter of technic in cleanliness; (4) overfilling of the cans; (5) carelessness in sealing the cans; (6) imperfect degree of processing. *No can that shows evidence of spoilage should be used as food.*

Emphasis has always been placed upon the necessity of a vacuum for the proper preservation of canned foods. Bacteriologists, however, have shown that sterile foods may be kept indefinitely in the presence of air. *Sterility*, then, is the great desideratum, both from the sanitary and economic standpoints. The time and temperature of processing varies with the food and its condition as to freshness and cleanliness. Allowing foods to stand before processing causes deterioration of the product and may render sterilization more difficult.

Practically all foods canned in the ordinary way contain some tin. The amount varies with the acidity, and also the age and temperature of the package and other factors. Canned lobster and shrimp are relatively active as solvents of tin on account of the amino acids they contain and are therefore packed in lacquered or enameled cans.

Fortunately, tin is not very toxic. Cushny stated that chronic poisoning from tin is unknown, and that animals present no symptoms when subjected to prolonged treatment with larger quantities of tin than are contained in any preserved foods. Schryver found no indications of cumulative action when as much as two grains per day is taken. So far as we know, tin plays no part of importance in toxicology.

The tin used to coat sheet iron is practically free of lead. The tin coating is not always perfect and may be injured in manipulation. The exposed iron is attacked by some foods and may spoil the contents by discoloration or metallic taste. For certain foods the tin is coated with lacquer, which is not acted upon by the contents of the package. However, the kind of product to be canned determines the selection of the lacquer coating. A special lacquer was developed for beer cans. Glass containers have some advantages, which are counterbalanced by expense, weight, bulk and breakage, both in handling and in processing.

## PREPARATION

**Cooking.** Cooking protects us against infection. Fortunately, most microorganisms pathogenic for man are comparatively thermolabile. Therefore, thorough cooking renders food reasonably safe so far as these dangers are concerned. Cook-



ing has other advantages. It softens the connective tissue and renders meat more tender. The bundles of fibrillae are loosened from each other, the albumin is coagulated, the flavors are improved, and new flavors are developed, which enhance digestibility. Cooking breaks open and softens the cellulose envelops and fibers of vegetables; the starch grains swell and burst, and the insoluble starch is converted into soluble starch or dextrin.

Metchnikoff in his "new" hygiene dwelt upon the great sanitary value of cooking. Perhaps no other single factor in preventive medicine protects us to an equal degree against infection. Metchnikoff believed that we should eat nothing in its raw state. This is as extreme as the cult which proclaims the contrary. The newer knowledge of nutrition confirms the experience that it is advantageous to eat a certain amount of raw food, particularly fruits and vegetables.

One of the important functions in the preparation of food is to render it savory, tender and appetizing. Foods that appear inviting aid digestion by stimulating the secretion and flow of the digestive juices. Foods that are rendered soft and tender are more readily digested, but it should not be forgotten that the teeth need exercise to keep them in good condition, and the digestive tract needs roughage.

Cooking has a few minor disadvantages (McCance and Shipp, 1933)—there is a loss of mineral salts, and some of the other nutritive constituents, also a diminution in the antiscorbutic property of food generally.

**POISONS AND PARASITES.** Heat also kills the true toxins,\* which are destroyed in a few minutes between 70° and 80° C. Foods may sometimes contain heat resisting poisons. Thus, boiling has no effect upon muscarine, a poison in certain toadstools. Heat also does not destroy a principle sometimes found in poisonous mussels. Furthermore, some toxins of bacterial origin are known to be heat stable.

Trichinae, according to some authorities, die at 65° C, but the United States Bureau of Animal Industry after repeated experiments places the thermal death point at a temperature of 55° C. Some writers state that cysticerci, or the larva stage of tapeworms, die at 52° C. The nonsporulating bacteria are for the most part destroyed at 60° C. Food thoroughly cooked throughout will always reach these temperatures, but much meat and many vegetable food substances are preferred rare or underdone, and, while the outside of a large piece of meat may be thoroughly cooked or even charred, the interior may be practically raw or at least not have reached the temperature necessary to destroy parasites. A dish of spaghetti, charred on the outside, may not kill typhoid bacilli in the center of the mass.

**TEMPERATURES.** Meat that is well cooked throughout always reaches from 60° to 70° on the inside. It should be remembered that heat penetrates a large piece of meat slowly. Küchenmeister found that joints require boiling for several hours for the interior to reach a temperature of 77° to 80° C. Perroncito placed a ham of about six kilos weight in cold water which was then raised to the boiling point. The water boiled when the interior of the ham was only 25° C. After 3 minutes, it was 35° to 40° C, and after two hours, the temperatures in different parts of the interior were 46°, 55°, 58°, 62°, 64°, and 67° C. Rupprecht found that boiling for 45 minutes, as practiced in Saxony, did not produce a higher tem-

\* The toxin of scarlet fever is heat resistant but not a danger in food.

perature than  $75^{\circ}\text{C}$  throughout, and this only in thin pieces of meat. He found that the interior temperature of a rapidly roasted sausage was only  $28.7^{\circ}\text{C}$ . Meat placed in a quick oven or boiled soon forms a hard, coagulated and insulated coating that retains the juices, but retards the penetration of the heat.

Delepine and Howarth carried out experiments upon the temperatures reached in baking meat pies. They noted that the temperature of the center of the pie, said to be underbaked, but having all the external appearances of being well baked, did not exceed  $47.2^{\circ}\text{C}$ . The center of a pie, obviously overbaked and acknowledged to be so, had not reached beyond  $86.6^{\circ}\text{C}$ . Delepine points out that pies might be so cooked that bacteria might continue to grow in their center during the greater part of their stay in the oven, and the bacteria would certainly not be killed.

**FIRELESS COOKERS.** The observations of Becker, Grove and others concerning the heat of cooking are practical and important in the preparation of food. Exposure to moist heat at  $60^{\circ}$  to  $70^{\circ}\text{C}$  for a long time has the advantage of cooking foods thoroughly throughout. This treatment prevents burning or the results of overheating; the juices are retained. The process requires little or no attention. Meat is thereby rendered tender and juicy, vegetables thoroughly soft, and the starch grains are all opened. Practical application of this method is found in the fireless cookers. These devices consist simply of a well-insulated box. The food is heated, placed in insulated compartments, and a temperature above  $70^{\circ}\text{C}$  maintained for many hours.

**COOKING UTENSILS.** Certain precautions are advisable in the choice of pots and pans used in cooking. Brass and copper are not advisable, and if used should be lined with tin and must be kept scrupulously clean. Copper acetate (verdigris) which sometimes forms in copper food containers, is greatly feared but is not very toxic. Acid foods should not be cooked in copper vessels, and milk and saccharine substances should not be kept in copper containers on account of the possibility of the organic acids dissolving the copper. Foods should not be fried in copper pans owing to the dissolving action of oleic, palmitic and stearic acids in lard and other fats. Mallory (1925) believes that chronic poisoning with copper is the cause of hemochromatosis. While the fully developed disease is relatively rare, he states that the early stages and lighter forms are fairly common but unrecognized. Iron, tin, nickel and aluminum ware are least objectionable. Enameled ware is satisfactory provided the glaze does not contain antimony or lead. If the glaze contains one of those metals it must be insoluble in acid of the concentration that may be found in food. Glassware, being insoluble, is least objectionable from this standpoint. Foods cooked in metal pots and pans always contain some of the metal, which is usually in solution in the form of salts, or may be in metallic form, or combined with chemical constituents of the food. The amount varies especially with the reaction, temperature, time of cooking and other factors. No harm is known to result from the small amounts of aluminum, tin and nickel which get into food from pots and pans.

**METHODS OF COOKING.** Much depends upon the method of cooking. The principal methods in ordinary use are: roasting, broiling, boiling, frying and stewing.

*Roasting* or *broiling* causes considerable shrinking, due mainly to loss of water. The heat coagulates the exterior of the meat and thus prevents the further loss of juices and drying up. In order to obtain adequate heating of the meat



throughout a large joint without burning and drying the exterior, it is necessary to baste it from time to time with hot melted fat. This also helps to form a protective coating.

In *boiling* the meat is placed either in hot or cold water, depending upon the object desired. If it is desired to maintain the flavors within the mass, the meat should be plunged into boiling water. This quickly coagulates the albumins at the surface. If a rich broth is desired, the meat should be placed in cold water and gradually heated. In this way the soluble proteins and extractives pass out into the surrounding water. The albumin of meat begins to coagulate at 134° F (56° C); the connective tissue is changed to gelatin and dissolved above 160° F (72° C). Long boiling makes meat fibers tough. Some of the mineral constituents are leached out, especially from vegetables.

*Frying* consists in placing meat or other substances into very hot fat, lard or vegetable oil. This causes a speedy coagulation of the surface similar in all respects to that brought about in the first mentioned process of boiling. The flavors and juices are thereby retained. If the fat is not very hot it will penetrate and cause the food to become greasy and unpalatable. Heating starches in fat favors greater thoroughness of cooking on account of higher temperature. Fried substances may be indigestible on account of the large amount of grease that adheres to and penetrates into them. It is, therefore, better to plunge food into deep fat, piping hot.

In *stewing* the meat is cut into small pieces and placed in cold water, which then is heated slowly to about 180° F (84° C), at which the whole is kept for several hours. If heated above 180° F the meat becomes tough, stringy, unpalatable and of diminished digestibility.

*Fermentation* is of great use in the preparation of foods. The best example is the leavening of bread. The yeast ferments the carbohydrates in the flour with the production of carbon dioxide and alcohol. The carbon dioxide renders the bread porous; the gas is held within the loaf on account of the glutinous property of the protein (gluten) in the flour. Fermentation is an adjunct in the preparation and preservation of many other foods and beverages, such as cheese, sauerkraut, vinegar, beer, wine, cider, etc.

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# 22

## MILK AND MILK PRODUCTS

Milk is our most important food. It is the best single food. The exceptional value of milk is due to the fact that it contains the essentials of a balanced diet; it is rich in some vitamins; the quality of its protein is especially good, the fat favors growth, and it has a high calcium content in readily usable form. Milk, furthermore, is palatable, readily digestible, and is subject to a great variety of modifications. Even at present prices, it is one of the cheapest of the standard articles of diet, and the most economical source of protein. In times of economic stress, it is a mistake to cut down on milk. In a low cost diet, the U. S. Department of Agriculture stipulates one quart daily from early childhood to adolescence, and one pint or more daily for adults.

The pastoral peoples of the world, whose diet has consisted largely of the products of dairy animals, have always displayed fine physical development. The peoples who have made liberal use of milk as a food have attained greater size, greater longevity, have been much more successful in the rearing of their young than the non-milk-using peoples, and have achieved much greater advancement in literature, science and art. Such development has a physiologic basis, and there seems every reason to believe that it is fundamentally related to nutrition (McCullum and Simmonds, 1925).

In the United States in 1954, there were 22,406,000 milch cows, producing 123,502 million pounds of milk. About one half of the amount consumed is taken as milk and table cream, one quarter as butter, and one quarter as cheese, ice cream, condensed, evaporated and dried milks. The average per capita consumption of fluid milk in the United States has risen to about one pint daily. It was 0.5 pint in 1900; 0.90 in 1925; and 0.86 in 1954. More milk is used in the north than in the south; very little is used in the tropics, and practically none in China, Japan and some other countries. About 16 per cent of the average dietary in the United States consists of milk and milk products.

While good milk has done more than any other single food to obtain and maintain health, bad milk was formerly responsible for more sickness and death than perhaps all other foods combined. There are several reasons for this: (1) Milk conveys a greater variety of infections than any other food. Bacteria grow well in milk at temperatures above 50° F; therefore, a slight infection may produce wide spread and serious results; (2) of all foodstuffs milk is the most difficult to harvest, handle, transport and deliver in a clean, fresh and satisfactory condition; (3) it is the most readily decomposable of all our foods; (4) finally, milk is the only standard article of diet obtained from animal sources that is likely to be consumed without being cooked.

Fresh milk products may be quite as dangerous as the milk from which they are made. Milk laws which ignore milk products are incomplete from the sanitary side, and will fail to accomplish their purpose from the economic side.

Milk is the only single substance whose sole function in nature is to serve as a complete food. It is a perfect food for the suckling of the same species. The milk of one mammal does not fit all the needs of the nursling of another kind: cow's milk is best for the calf, bear's milk for the cub, lion's milk for the whelp, and mother's milk for the baby. After weaning, milk is the best single food to promote growth and nutrition in children. All students of dietetics favor the free use of milk for growing children, who may well take as much as a quart a day, depending upon the amount and character of the remainder of the diet, and also upon individual idiosyncrasies. Milk is quite as nutritious and beneficial whether drunk as milk or taken as part of various food preparations.

As a sole article of diet for adults, milk is low in iron and some vitamins; it has too much water and too little roughage. Adults should get no less than a pint of milk a day in the diet.

In view of the many advantages and few drawbacks, sanitarians unanimously encourage the production and use of pure milk, and discourage the distribution and use of poor milk. It is the only food for which there is no effective substitute.

Practically all large cities in the United States forbid the sale of loose milk. Milk is such a precious article of food and so susceptible to infection that it deserves to be handled with respect. It is entitled to an individual package. The bottle should be clean and sterile and effectively sealed, at least the cap should cover the lip.

**Composition.** Milk is the secretion of the mammary gland. In composition it is exceedingly complex, consisting chiefly of water; several proteins in colloidal suspension; fats in emulsion; sugar, and a number of inorganic salts in solution; also vitamins, phosphatides, enzymes, as well as antibodies, cells, gases, pigments and other substances. Milk from all species of animals shows a general agreement in physical properties and composition, containing essentially the same ingredients, which differ in relative amounts.

In its fresh state, the average figures for cow's milk are as follows: it has a specific gravity of 1.028 to 1.034; it freezes at a temperature somewhat lower than the freezing point of water ( $-0.550^{\circ}\text{C}$ ); the electrical conductivity is about  $5.0 \times 10^{-4}$  for cow's milk, and about  $22.6 \times 10^{-4}$  for human milk. The specific heat of whole milk containing 3.17 per cent of fat is 0.938 at  $15^{\circ}\text{C}$ . The coefficient of expansion is greater than that of water. Milk shows no maximum of density above  $1^{\circ}\text{C}$ . It contains about 20 calories per ounce.

Freshly drawn milk of carnivorous animals is, as a rule, acid in reaction. This is probably due to carbon dioxide and acid phosphates. Human milk and that of most of the herbivora is slightly alkaline; cow's milk has been described as amphoteric. Fresh cow's milk is slightly acid to phenolphthalein; but alkaline to methyl orange, indicating that the acidity is due in part to the acid phosphates. The pH values of fresh cow's milk range between 6.5 and 6.8; fresh mother's milk varies between 7.1 and 7.6.

Under the microscope milk is found to contain fat globules and cells, as well as bacteria, debris and other objects.

The gases dissolved in milk are oxygen, nitrogen and carbon dioxide (3 to 4



per cent by volume). These gases are carried into milk mechanically from the air in the process of milking. Other substances found in milk, but in small quantities, are lecithin, cholesterin, citric acid, lactosin, orotic acid and ammonia.

Van Slyke and Bosworth (1915) suggest the following as representing the principal constituents of milk more closely than previous statements. The amounts are based on milk of average composition:

<i>Constituents</i>	<i>Per Cent</i>
Fat . . . . .	3.90
Milk sugar . . . . .	4.90
Proteins combined with calcium . . . . .	3.20
Dicalcium phosphate ( $\text{CaHPO}_4$ ) . . . . .	0.175
Calcium chloride ( $\text{CaCl}_2$ ) . . . . .	0.119
Monomagnesium phosphate ( $\text{MgH}_4\text{P}_2\text{O}_8$ ) . . . . .	0.103
Sodium citrate ( $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$ ) . . . . .	0.222
Potassium citrate ( $\text{K}_3\text{C}_6\text{H}_5\text{O}_7$ ) . . . . .	0.052
Dipotassium phosphate ( $\text{K}_2\text{HPO}_4$ ) . . . . .	0.230
Total solids . . . . .	12.901

The composition of cow's milk may be understood from the schemes prepared by Lucius L. Van Slyke and S. M. Babcock, given on page 843.

**MILK PROTEINS.** The proteins constantly found in milk are casein, an albumin, a globulin and an alcohol soluble protein. The four proteins are immunologically distinct. The casein and the lactalbumin are basic nitrogenous constituents of milk and occur also in colostrum. Together, the proteins are complete, containing all the amino-acids in proper proportions to build tissue. Traces of fibrin, mucin and other proteins sometimes occur.

The proteins in milk of a given breed are quite constant in composition, but vary in amount. There is even an individual variation in cows of the same breed. The amount of protein in mixed milk of cows of the same breed is quite constant. There is always more fat than protein in the complete milk of a healthy cow. In a sanitary analysis of milk it is not the rule to make a special test for proteins. They may be estimated by subtracting the fat, sugar and ash from the total solids.

*Casein* is a highly specialized protein found in the secretion of the milk gland of all mammals, but nowhere else in nature; it is a nucleo-albumin, and as such contains phosphorus. Casein is a complete protein. It is insoluble in water, but by virtue of its property as an acid it forms soluble salts with alkalis. There are two series of casein salts, basic and neutral; solutions of the latter have a milky appearance. In milk, casein is found dissolved in the form of a neutral calcium salt, which accounts in part for the white opalescent appearance of milk whey. Casein exists in milk in combination with calcium phosphate. It is not coagulated by heat in an alkaline medium, but is precipitated by acids, for the reason that acids take the calcium from the calcium phosphate, and thus throw the casein out of solution as a curd. This flaky or lumpy precipitate is again soluble in lime-water and dilute alkalis. Casein is also precipitated by pepsin. Cow's milk contains about 2.5 per cent of casein; woman's milk between 0.5 and 0.75 per cent.

*Lactalbumin* is similar to the serum albumin of the blood, but it appears to differ from this in some particulars. It coagulates by heating to  $70^\circ\text{C}$ , but not with dilute acids, and is precipitated by a saturated solution of ammonium sulphate, but, in

Milk = 100.0	<table> <tr> <td>Water = 87.1</td> <td>Fat</td> <td rowspan="3"> <table> <tr> <td rowspan="3">= 3.9</td> <td rowspan="3">Nitrogen compounds = 3.2</td> <td rowspan="3"> <table> <tr> <td>Casein</td> <td>= 2.5</td> </tr> <tr> <td>Albumin, etc.</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>3.2</u></td> </tr> </table> </td> </tr> <tr> <td>Solids = 12.9</td> <td></td> </tr> <tr> <td><u>100.0</u></td> <td></td> </tr> </table> </td> </tr> <tr> <td></td> <td> <table> <tr> <td>Solids not fat = 9.0</td> <td> <table> <tr> <td>Milk sugar</td> <td>= 5.1</td> </tr> <tr> <td>Ash (salts)</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>9.0</u></td> </tr> </table> </td> </tr> <tr> <td></td> <td><u>12.9</u></td> </tr> </table> </td> </tr> <tr> <td></td> <td>(Carbon dioxide</td> </tr> </table>	Water = 87.1	Fat	<table> <tr> <td rowspan="3">= 3.9</td> <td rowspan="3">Nitrogen compounds = 3.2</td> <td rowspan="3"> <table> <tr> <td>Casein</td> <td>= 2.5</td> </tr> <tr> <td>Albumin, etc.</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>3.2</u></td> </tr> </table> </td> </tr> <tr> <td>Solids = 12.9</td> <td></td> </tr> <tr> <td><u>100.0</u></td> <td></td> </tr> </table>	= 3.9	Nitrogen compounds = 3.2	<table> <tr> <td>Casein</td> <td>= 2.5</td> </tr> <tr> <td>Albumin, etc.</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>3.2</u></td> </tr> </table>	Casein	= 2.5	Albumin, etc.	= 0.7		<u>3.2</u>	Solids = 12.9		<u>100.0</u>			<table> <tr> <td>Solids not fat = 9.0</td> <td> <table> <tr> <td>Milk sugar</td> <td>= 5.1</td> </tr> <tr> <td>Ash (salts)</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>9.0</u></td> </tr> </table> </td> </tr> <tr> <td></td> <td><u>12.9</u></td> </tr> </table>	Solids not fat = 9.0	<table> <tr> <td>Milk sugar</td> <td>= 5.1</td> </tr> <tr> <td>Ash (salts)</td> <td>= 0.7</td> </tr> <tr> <td></td> <td><u>9.0</u></td> </tr> </table>	Milk sugar	= 5.1	Ash (salts)	= 0.7		<u>9.0</u>		<u>12.9</u>		(Carbon dioxide
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(Babcock)

Milk = 100.0		Total solids = 12.7	
Butter fat = 3.6		Fat ..... 3.6	
Olein ..... Palmitin ..... Stearin ..... Myristin .....		Glycerides of insoluble and nonvolatile acids... 3.3	
Butin (trace) Butyrin ..... Caproin ..... Caprylin (trace) Caprinin (trace)		Glycerides of soluble and volatile acids ..... 0.3 <u>3.6</u>	
Casein ..... 3.00 Albumin ..... 0.60 Lactoglobulin ..... Galactin ..... 0.20 Fibrin (trace)		Containing nitrogen .... 3.8 <u>3.80</u>	
Milk sugar ..... Citric acid ..... Potassium oxide ..... 0.175 Sodium oxide ..... 0.070 Calcium oxide ..... 0.140 Magnesium oxide ..... 0.017 Iron oxide ..... 0.001 Sulphur trioxide ..... 0.027 Phosphoric pentoxide ..... 0.170 Chlorine ..... 0.100 <u>0.7</u>		Solids not fat ... 9.1 <u>12.7</u>	
Milk serum = 96.4 <u>100.0</u>		Ash ..... 0.7 <u>9.1</u>	
Water .....		87.3 <u>100.0</u>	



all other albumins, is not precipitated in a neutral solution of sodium chloride and magnesium sulphate. Lactalbumin contains sulphur but no phosphorus. It is present in amounts varying from 0.2 to 0.8 per cent, but is much more abundant in colostrum.

*Lactoglobulin* occurs in milk merely in traces, while colostrum is comparatively rich in this protein. It coagulates at 75° C, it is precipitated in the same way as serum globulin, and, like serum globulin, is insoluble in water, but is soluble to some extent in weak salt solution. Lactoglobulin and serum globulin are chemically indistinguishable.

**FAT.** The fat is suspended in the milk serum in the form of an emulsion. The droplets or globules vary in size. On the average they are smaller in milk from Holstein than from Jersey, Guernsey, or shorthorned breeds. Under the microscope some of the fat globules seem to have an albuminous membrane, but this interpretation is questioned. The fat droplets are lighter than the milk whey, therefore they rise on standing (gravity cream), or may readily be separated by centrifugal force (centrifugal cream). Cream, or top milk, does not consist of fat alone, but contains a portion of each of the constituents of the milk; it is simply milk rich in fat. Churning causes the fat globules gradually to coalesce into larger drops and lumps to form butter.

The first milk drawn from the udder is commonly poor in fat. This is known as "fore" milk. The middle portion contains about the average percentage, and the last, known as "strippings," is always the richest in fat. The strippings may contain as much as 9 or 10 per cent.

Milk fat consists of a mixture of different neutral fats, the principal of which are olein, palmitin and stearin. These are neutral triglycerides of the corresponding fatty acids. Besides these are found the triglycerides of myristic, butyric and caprylic acids. The last two are volatile and give to butter its characteristic odor and flavor. Crowther and Hynd (1917) state that the only acids present in more than minimal proportions are the unsaturated acid, oleic acid, and the eight saturated acids of the acetic series ( $C_4$  to  $C_{18}$ ), namely, butyric, caproic, caprylic, capric, lauric, myristic, palmitic and stearic acids. The composition of the fat is subject to variation, depending upon racial or individual peculiarities, and other conditions.

Milk fat is rich in vitamin A. This vitamin promotes growth; its absence induces xerophthalmia and serious disturbances of nutrition. Osborne and Mendel have shown that butter fat may have a blast of steam passed through it for two hours and still retain its peculiar growth-promoting properties. This observation is in harmony with those of McCollum and Davis, that heating butterfat to the temperature of boiling water does not affect its peculiar dietary value. It is apparent, therefore, that any conditions to which milk fats are liable to be subjected during the cooking of foods will not greatly alter its value as a source of vitamin A. Evaporated and dried milks also retain the virtues of this vitamin.

Milk fat contains ergosterol, and vitamin D appears to be a stereoisomer of ergosterol. The amount of vitamin D in milk fat varies from a trace to about 1 Steenbock units per quart, depending on the vitamin D in the food intake of the cow. Ordinarily in wintertime the milk of stall-fed cows contains only traces of vitamin D.

It is now clear that milk fat has no superior among hydrocarbons in dietetic or nutritional value. It is the chief source of vitamin A in our diet.

The percentage of butterfat in milk has long been one of the standards by which milk is tested. The richness of milk gauged by the amount of fat it contains is more of an economic than a sanitary question. Milk with a lower percentage of fat from Holstein cows is relatively as nutritious as richer milk from Jersey and Guernsey cows. Even skimmed milk containing little or no fat is a valuable food. The problem is one of honest labeling and the marketing of various grades at prices corresponding to their nutritive contents. When the standard for butterfat in milk is relatively low, say 3.25 per cent, it is a temptation for dairy men to standardize or adjust. A high fat standard encourages the breeding of better cows.

In normal milk the larger proportion of fat droplets agglutinate into tiny clusters or masses. At a temperature of  $65^{\circ}\text{C}$  or above, these clusters are broken up and the globules are more homogeneously distributed throughout the liquid. When milk is atomized under a pressure of about 1,500 pounds or over, at a temperature of about  $75^{\circ}\text{C}$  the individual fat globules are broken up into fine particles, which remain as a uniform and permanent emulsion known as "homogenized milk." This process applied to cream increases its volume and viscosity, so that cream containing 20 per cent butterfat appears to have the body and richness of a 30 per cent cream.

Heat hinders the rising of the fat drops; if heated above  $63^{\circ}\text{C}$  for 40 minutes or longer the formation of the cream line is retarded or prevented. For this and other reasons, therefore, the richness of milk cannot always be judged by the depth of the cream layer.

Researches of Huebner, Keller and Czerny show that the fats rather than the proteins are the cause of much of the digestive disturbances in infants. When the fat is excessive in amount the infant at first seems to thrive, but sooner or later loses weight and appetite, and shows other symptoms, associated with stools composed largely of fat soaps and of a pale gray, hard and dry constituency. The alkaline bases are so largely drawn upon from the body to saponify the excessive amount of fat in the intestines, that a condition resembling acidosis may appear; furthermore, fermentative changes take place in the intestines and the "catastrophe" ensues.

Fat is the most variable constituent in milk. The amount varies with different animals, and even in the same animal from time to time.

**MILK SUGAR, OR LACTOSE.** Milk sugar, or lactose ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ), is peculiar to milk; it is found nowhere else in nature. Commercially, milk sugar is obtained from whey as hard rhombic crystals, which have a slightly sweet taste and are soluble in six parts of cold water. Lactose is readily acted upon by micro-organisms and reduced to glucose and galactose; the glucose is further changed to lactic acid. This is the common cause of sour milk (page 856).

Lactose, like glucose, reduces Fehling's solution when heated; it is dextrorotatory. When heated above the boiling point of water it changes to a brownish color as a result of the formation of lactocaramel.

The amount of lactose in milk of any given species is remarkably constant. Goat milk contains (7 per cent) much more than cow's milk (4.9 per cent).



Lactose is not digested and absorbed as quickly as other sugars and therefore favors the fermentative flora in the intestines (see page 856).

**VITAMINS.** The early impression that milk must be rich in all the vitamins has met with some disappointments. Milk may be rated as an excellent source of vitamin A, a fair to good source of vitamin B<sub>1</sub>, a variable source of vitamin C, a poor source of vitamin D and an excellent source of vitamin B<sub>2</sub>; and contains vitamins E, K, biotin, choline, folic acid, inositol, niacin, and pantothenic acid. The diet plays an important part in determining the amount of each vitamin, except B and G, in milk. (See vitamins, page 591.)

The fat of milk is a rich source of *vitamin A*. Therefore, butter, cream, ice cream and all kinds of cheese which are made from whole milk or mixtures of milk and cream are outstanding sources of vitamin A. Milk itself, with its natural high water content, is not a concentrated source of vitamin A, but in the quantities in which it should enter the dietary it becomes an important source. Dairy products taken together constitute the chief source of vitamin A in the American and European food supply.

The amount of vitamin A in mixed market milk is reliable and fairly uniform. It is stable and heat resistant.

Compared on the basis of solid matter, milk is a good source of *vitamin B*. Milk, however, is not outstandingly rich in this vitamin, but is a constant and reliable source.

Vitamin B<sub>1</sub> as it exists in milk is comparatively stable to heating at 100° C. It has been found that there is no measurable diminution of it in milk powder when heated dry with free access of air at 100° C even when this heating was continued for 48 hours.

The *antiscorbutic* property of milk is variable, being readily oxidizable, and the baby, whether nursed or bottle fed, should have orange juice or tomato juice.

Since the animal body does not synthesize vitamin C nor carry any large store of it, the amount of this vitamin in milk must be more or less dependent upon the food of the nursing mother or of the lactating animal, as the case may be.

According to Hess, a pint per day of average milk supplies the antiscorbutic requirement of a child. If the antiscorbutic value is materially lessened by oxidation, heating or aging of the milk or by faulty feeding of the cow, more milk will be required.

Brief boiling of milk in open utensils, as in ordinary household practice, has been reported by different investigators to result in losses of one-fifth to one-half its vitamin C content. The diminution of antiscorbutic value involved in commercial pasteurization is probably of similar order. Milk in clear glass bottles standing on the doorstep in the sunlight will lose vitamin C rapidly.

That Hart and others report practically complete destruction of vitamin C in commercial "evaporated," while Hess and also Hume find it well conserved in commercial "condensed" milk, is in accordance with the different heat treatments involved.

Hess, working with dried milk prepared by a roller process, and Cavanah, Dutcher and Hall, working with spray-dried milk, both report good conservation of vitamin C in these products. The vitamin is more stable in the dry state than in the aqueous solution.

Ordinary market milk contains only about 5 to 12 Steenbock units of *vitamin D* per quart. This may readily be increased to 50 or more units by feeding irradiated yeast to the cow, irradiating the milk, or by adding cod liver oil concentrates or irradiated ergosterol to the milk (page 601). It may also be increased by irradiating the cow. Commercial practice is to add about 400 units of vitamin D per quart to milk sold as vitamin D milk.

Whole milk has important antirachitic value, due in part to the vitamin D which it contains when produced under favorable conditions, and in part to the fact that it contains liberal and well balanced proportions of calcium and phosphorus.

The nutritive condition of the mother influences the storage of vitamin D in the body of the baby before its birth, and her bodily store of this vitamin (or lack of it) affects the antirachitic potency of her milk.

The total amount of vitamin D obtained through milk fat is considerable because of the consumption of the latter not only in the form of milk itself but also of cheese, butter, cream and ice cream.

*Vitamin E* has been found in milk and butter.

There is evidence that milk as ordinarily produced is a rich and reliable source of *vitamin G* ( $B_2$ ) at all seasons of the year. When account is taken of the amounts ordinarily eaten in reasonably well balanced dietaries and food supplies, milk is doubtless the most important source of vitamin G for the American and European peoples.

**FERMENTS.** Milk contains a large number of active ferments or enzymes which have taken a back seat since the discovery of vitamins. Milk also possesses certain other properties common to blood and living tissues, but, while milk may properly be regarded as a vital fluid, it is not a living fluid as was formerly claimed. In fact, milk begins to decay the moment it is drawn; oftentimes before.

Some of the ferments in milk are normal constituents of that secretion, while others are produced by bacterial activity. Many tests have been devised to determine the kinds and activity of the ferments in milk. The tests which have been most frequently and most successfully used are those for catalase and reductase, and more recently phosphatase.

The enzymes in milk are the following:

**Phosphatase.** Phosphatase or phosphomonoesterase is a heat labile enzyme commonly present in raw milk which is known for its property of hydrolyzing mono-esters of phosphoric acid. By chance the heat treatment required to inactivate this enzyme in milk is almost exactly equivalent to that required to be applied to milk by the standard definition of pasteurization. Kay and Graham utilized these properties in their phosphatase test for pasteurization. Modifications of this test, particularly those of Gilcreas and Davis, Scharrer and Sager, are now extensively used in the official control of public milk supplies. The basic principle of the test is that the phosphatase enzyme if present in milk, upon incubation will break down an added standard buffered di-sodium-phenyl phosphate solution releasing free phenol which is readily detectable in cleared solution by a simple color test using Folin's or Gibb's reagent. Small quantities of phosphatase enzyme remaining as a result of incomplete pasteurization or the addition of as little as 0.1 of one per cent of raw milk to pasteurized will release a detectable quantity of phenol, making the test extremely useful.



*Galactase.* Galactase is a proteolytic ferment, similar to trypsin. It was found by Babcock and Russell to be abundant in separator slime. Ordinarily galactase by itself acts too slowly to cause any material change in the proteins in the short intervals which elapse between the withdrawal of the milk from the animal and its consumption as food. Snyder claims that this enzyme probably assists digestion, in that when milk is used in a mixed diet the proteins have been found to be from 4 to 5 per cent more digestible than when milk is omitted from the diet.

*Lactokinase.* Hougardy has shown that milk contains a ferment or a kinase similar to enterokinase. Lactokinase has been found to accelerate the digestion of proteins by pancreatic juice. This property is destroyed by heating the milk at 73° to 75° C.

*Lipase.* This fat-splitting ferment was found in milk by Marfan and Gillet. Human milk exhibits this property to a higher degree than cow's milk. The former has a lipolytic activity of from 20 to 30 on Harriot's scale, while cow's milk shows an activity of only six to eight. Lipase withstands cold, but is destroyed by heating to 65° C; it is nondialyzable and is held back by a porcelain filter. It probably hydrolyzes the higher fats of milk, at least to some extent, and accounts for the so-called "cappy" or slightly rancid flavor in milk.

*Catalase.* Milk contains no true oxidases or oxidizing ferments proper (Kastle). It decomposes hydrogen peroxide and has the power of effecting the oxidation of a considerable number of easily oxidizable substances in the presence of hydrogen peroxide or ozonized oil of turpentine. In other words, milk contains catalase and peroxidase. Catalase is widely distributed among animals and plants; in milk it is probably of bacterial origin. Jolles has pointed out that human milk decomposes five or six times as much hydrogen peroxide as cow's milk. Considerable importance has been attached to this difference, which has also been used to distinguish human milk from cow's milk. Little is known of the function of catalase. Hydrogen peroxide is probably formed in both animal and vegetable tissues during vital activities. The catalase would destroy it and thus prevent its accumulation in the cell, which otherwise would destroy its life.

*Peroxidase.* Milk contains substances capable of inducing the oxidation of guaiacum and other readily oxidizable substances by means of hydrogen peroxide or ozonized oil of turpentine. These substances are known as peroxidases. The peroxidases are destroyed when milk is heated to 80° C. The color reactions for these ferments are a convenient test to determine whether milk has been heated beyond a certain temperature. The interpretation of this reaction must, however, be guarded, as Gillet and Kastle found that even normal fresh milks vary in the amount of peroxidases which they contain.

*Reductase.* Raw milk possesses reducing properties; for example, it reduces Schardinger's reagent, which consists of a solution of methylene blue containing small amounts of formaldehyde. The reductases in milk are probably of bacterial origin. On account of the bacterial origin of both the catalases and reductases in milk, the detection of these enzymes has a sanitary significance.

*Diastase (Amylase).* Béchamp in 1882 isolated from milk a ferment which hydrolyzes starch and converts it into sugar as readily as diastase. These observations have been confirmed. The presence of diastase in milk is now used as the basis of an important method of distinguishing between raw and pasteurized milk.

**LEUKOCYTES.** A large number of cells are normally present in milk. These are not to be regarded as the result of inflammation, unless they have the characteristics of "pus" cells. Those found in normal milk are leukocytes and degenerated epithelial cells. The number of cells in milk is greatly increased in the presence of mastitis or "garget"; toward the end of lactation; on approaching calving time; during periods of excitement; and by various other factors. Hucker (1933) suggests that the presence of more than 500,000 cells per ml. indicates an abnormal or pathologic condition in the udder.

The Breed method, commonly used, consists in staining 0.01 ml. of the milk spread over an area of 1 square centimeter on a glass slide—dried and stained with methylene blue or other standardized stain. Both the cells and the bacteria may thus be counted. This method does not distinguish between live and dead bacteria, although it is evident that all dead bacteria do not take the stain.

An excess of pus cells, especially if associated with streptococci, indicates inflammation of the udder. When a mixed milk shows such an excess, say more than a million per milliliter, it may be run down to an individual cow with mastitis. When this cow is eliminated, the mixed milk clears up. This is the usual picture and practice.

**MINERAL CONSTITUENTS.** Mineral constituents of milk are of the highest importance to the growing animal. The inorganic salts of milk have already been stated.

Milk is the best source of calcium in the diet, both on account of the quantity and the usable form in which it exists. Sherman and Hawley (1922) have shown that growing children need one liter of milk a day for optimum calcium intake. Children up to the age of puberty, therefore, should get about a quart of milk a day, adults at least a pint. The vegetables are the only other class of foods where calcium content is high enough to be a source of the mineral in children's diets, but children do not utilize the calcium of vegetables as efficiently as they do that of milk.

Milk also contains useful amounts of other inorganic constituents, potassium, phosphorus, chlorides, sulphates, etc. The buffer value of milk protects the gastric glands against strain.

Milk is deficient in *iron*, averaging only 0.00024 per cent.\* An exclusive milk diet may, therefore, cause iron anemia. Milk is also deficient in copper and manganese. The iodine content depends upon the iodine intake of the cow.

The mineralization of milk is proposed. This would include the addition of iron, copper, iodine, manganese and other elements. The project does not meet with approval of health authorities except when accomplished through the feed of the cow. The content of some minerals, such as iodine, can be increased by adding the element to the cow's feed but the content of some other minerals, such as iron, cannot be so increased.

**Colostrum.** Colostrum is the fluid secreted by the mammary gland during the first few days after birth and before lactation becomes established. Colostrum and milk differ markedly in appearance, quality, composition and function. Colostrum

\* It has long been known that there is deposited in the liver of the newborn animal a reserve supply of iron, which ordinarily suffices to tide it over the suckling period. Ordinary drinking water almost always contains small amounts of iron, and this doubtless aid in some degree in preventing iron starvation in the infant.



contains on an average much less fat, but four times as much protein as the milk of the same cow. This increase is mainly due to the presence of a great quantity of globulin.

In women, colostrum does not appear for at least 12 hours after delivery. Not more than 5 ml. is secreted in the first 24 hours, and not more than 90 ml. after 48 hours. The cow's udder, on the other hand, is filled with colostrum at the time of parturition. The calf takes about two pounds at the first feeding shortly after birth.

Theobald Smith and his co-workers (1922, 1923, 1925) discovered that colostrum is the chief agent for transferring protective antibodies to the newborn calf. It is difficult to raise a calf if colostrum is withheld or even postponed 24 to 36 hours. Without colostrum, calves usually succumb during the first week to intestinal infections and interstitial focal nephritis caused by a particular type of colon bacillus, which is nonmotile, indol-producing, and fails to act on saccharose. Colostrum, then, is essentially protective against miscellaneous and ordinary bacteria which are harmless later on when the immunity functions of the calf have begun to operate.

The calves are protected whether the colostrum is fed to them or injected intravenously or subcutaneously. The specific agglutinin against this type of colon bacillus is present in the cow's blood and in colostrum, but is absent from the blood of the newborn calf; it appears within 15 minutes of a feeding of colostrum.

Human colostrum seems to be less important. No harm has been discovered in infants deprived of it altogether. The human placenta is much more permeable than that of ruminants, because there is only a single layer of cells separating the maternal blood from the fetal blood, whereas in ruminants the placenta has a barrier of a three-cell layer. Antibodies pass the human placenta readily; thus diphtheria, scarlet fever and tetanus antitoxins have been demonstrated in the cord blood. Measles and other antibodies have been extracted from the human placenta by McKhann. The difference in the amount and composition of colostrum in man and cow corresponds to the difference in the requirements and functions of the baby and the calf.

**The Mammary Gland as an Excretory Organ.** The mammary gland acts to some extent as an excretory organ, in the sense that waste nitrogenous substances filter through from the blood into the milk. Among these are the so-called non-protein nitrogenous extractives, amino acids, urea, creatine, creatinine and uric acid. Milk may therefore occasionally become a vehicle of substances that are undesirable as a dietary ingredient. Every efficient physiologic mechanism fails at times. Foreign proteins may occur in the milk, but in minute quantities, demonstrable only by anaphylactic reactions. More important is the excretion of drugs and foreign substances in milk.

**Excretion of Drugs in Milk.** The following drugs taken by the mouth have been found in the milk of nursing women: aspirin, iodine, mercury (calomel), arsenious acid, potassium bromide, and probably also hexamethylenamine, salicylic acid and salicylates, ether, antipyrine, bromides, caffeine and many others; the list is long. It is probable that opium, all volatile oils, purgative salts and rhubarb are excreted to a certain extent in the milk. It is well known how readily the flavor of cow's milk is affected by turnips, garlic, wild onions, moldy hay and grain, or damaged ensilage. Fermented distillery waste gives a bad flavor and may also cause

the secretion of small quantities of alcohol in the milk. The importance of these facts is self-evident. Cows in pastures sometimes feed on poisonous weeds, and these poisons may pass into the milk. Certain substances, as ensilage, when fed to cows, cause a laxative property to appear in the milk, and thus it is possible to affect the baby through the feed of the cow. The color of milk is also influenced somewhat by the feed, accounting for the richer color when cows are put out to pasture in the spring.

**Differences between Cow's Milk and Woman's Milk.** The following table modified from Rotch summarizes the principal points of differences between cow's milk and human milk.

WOMAN'S MILK DIRECTLY FROM THE BREAST	COW'S MILK, FRESHLY MILKED
Reaction, amphoteric (more alkaline than acid)	Amphoteric (more acid than alkaline)
pH values, 7.1 to 7.6	pH values, 6.5 to 6.8
Water, 87 to 88 per cent	86 to 87 per cent
Mineral matter, 0.20 per cent	0.70 per cent
Total solids, 13 to 12 per cent	14 to 13 per cent
Fats, 4.00 per cent (relatively poor in volatile glycerides)	4.00 per cent (relatively rich in volatile glycerides)
Milk sugar, 7.00 per cent	4.75 per cent
Proteins, 1.50 per cent	3.50 per cent
Caseinogen, $\frac{1}{3}$ to $\frac{1}{2}$ of the total proteins	2.66 per cent
Whey-products, $\frac{2}{3}$ to $\frac{1}{2}$ of the total proteins	0.84 per cent
Coagulable proteins, small proportionately	Large proportionately
Coagulation of proteins by acids and salts, with greater difficulty. Curds small and flocculent	With less difficulty, curds large and tenacious
Coagulation of proteins by rennet, does not coagulate readily	Coagulates readily
Action of gastric juice, proteins precipitated but easily dissolved in excess of the gastric juice	Proteins precipitated but dissolved less readily
Ash, 0.2 to 0.3 per cent	Ash, 0.6 to 0.7 per cent

The above are averages, for the quantity and quality of milk secreted depends upon the size and anatomical structure of the gland, the amount and kind of food ingested, heredity, environmental conditions, such as fresh air, sunshine and the amount and intensity of work, rest and exercise, and also the emotional psychic make-up of the person, etc. The constituents of milk change during the progression of the period of lactation. This change occurs not only from day to day but also varies at different times of the day, and also between the first and last halves of nursing. The fat, protein, nitrogen, total solids and phosphorus tend to increase with the progression of nursing.

The differences between these two milks are greater than the table indicates. While cow's milk may be modified to approximate woman's milk in composition, it can never be just the same or just as good for infants.

Cow's milk is more opaque than woman's milk, although the latter may contain a greater percentage of fat. This is due to the opacity of the calcium-casein, which is present in greater proportion in cow's milk. Cow's milk is faintly acid or amphoteric when freshly drawn, but ordinarily is distinctly acid in reaction when consumed. Woman's milk is amphoteric or alkaline.

There is more than twice as much protein in cow's milk as in woman's milk.



The reason for this is obvious, when we recall that the size and ratio of growth of the calf to that of the infant is about as two to one. Furthermore, the protein in cow's milk consists chiefly of casein (3.02 per cent) and little lactalbumin (0.53 per cent), while woman's milk contains 0.59 per cent of casein and 1.23 per cent lactalbumin. Furthermore, while casein is a complete protein, it is relatively deficient in the indispensable amino-acid cystine. The sugar in the two milks varies greatly in amount, but not in kind. Cow's milk contains almost four times the amount of inorganic salts compared to woman's milk. Of more importance, cow's milk contains more calcium and phosphorus than breast milk, and the ratio of calcium to phosphorus is lower in cow's milk. These differences have an important bearing upon infant metabolism. There is no great difference in the average amount of fat in the two milks; however, both in woman's milk and in cow's milk the fat is a variable constituent. Mother's milk is richer in diastase than cow's milk.

Table 22-1. The inorganic food substances in milk

	Woman's Milk gm. per 100 ml.	Cow's Milk gm. per 100 ml.
Na	.010	.051
K	.047	.143
Ca	.034	.120
Mg	.005	.012
Fe	.0001	.0002
Cl	.035	.106
P	.015	.093
S	.005	.034

The energy and structural components also show differences:

WOMAN'S MILK

Total solids, 12.5 gm. per 100 ml.  
Partition of solids:

	Per Cent		Per Cent
Fat	28	} Energy	88
Sugar	60		
Protein	10	} Structure	12
Salts	2		

COW'S MILK

Total solids, 13.0 gm. per 100 ml.  
Partition of solids:

	Per Cent		Per Cent
Fat	31	} Energy	67
Sugar	36		
Protein	27	} Structure	33
Salts	6		

*The importance of mother's milk for the baby cannot be emphasized too often. There is no adequate substitute. Breast nursing is best for the baby and best for the mother. Mother's milk contains specific and useful antibodies and other unknown qualities, inadequately represented in cow's milk. Cow's milk can be modified to*

resemble human milk, but there are essential differences that may have remote effects upon the soundness of the teeth, the resistance of the tissues, etc.\* Babies should be nursed at least three or four months unless there are contraindications.

The diet of the mother affects the quantity and quality of the milk. The lactating woman needs a generous diet, varied with vitamins, well balanced and with about one-third more calories. The nature of the diet even influences the quality of the proteins in the milk. The mother should lead a calm life, for emotional stress, fatigue and worry may affect the milk. She needs exercise, sunshine, plenty of rest and food for two.

**Milk Standards.** The word "standard" used in this connection is not intended to imply excellence, but simply to express the lowest limit that the law permits. There are at least four standards by which milk should be judged: (1) *physical standards*, specific gravity, temperature, taste, odor, etc.; (2) *chemical standards*, especially the percentage of fat and total solids; (3) *bacteriological standards*, the number of bacteria per ml. and absence of pathogens; (4) *sanitary standards* determined by veterinary and medical inspection. Standards have also been established for pasteurization, production, transportation and handling. All are necessary for the satisfactory control of a milk supply.

It has been found an advantage to keep the butterfat standard relatively high and the total solids at a minimum of 12 per cent. This allows 8.5 per cent for solids not fat, such as the proteins, milk sugar and inorganic salts. A 3.25 per cent butterfat and a 12 per cent total solids is the minimum required by many sanitary codes. This should be 3.5 per cent fat for 12 per cent total solids, which is the relation in mixed milk at present.

If the law recognizes a low standard for total solids, it permits manipulation, especially watering. Low fat and high total solids permit skimming. It also permits the production of milk from inferior cows. High standards encourage good dairy methods, require good food, and place a premium upon the better breeding of milch cows.

The ratio of fats to total solids is used to detect skimming; however, it is possible to skim milk within limits, without detecting it by this method.

If dependence is placed upon the total solids, mistakes may also occur. The total solids represent the proteins, fats, sugar and inorganic salts. They may readily be tampered with. Skimming can readily be determined by a fat-protein ratio. Watering does not alter this ratio, but may be detected by a cryoscopic examination.

A milk ordinance and code has been drawn up by the U. S. Public Health Service (1953) and is being widely adopted.

**Grades of Milk.** Milk varies greatly in sanitary quality and in nutritive value. These differences are not obvious to our unaided senses. Milk should, therefore, be graded just as other commodities, such as wheat, beef, fruit, coal, etc., are graded.

From the standpoints of health and sanitation, the grading of milk was very useful during the period in which sanitary standards were being raised. Before the tuberculin testing of cows on an area basis was practiced extensively, work was stimulated in some areas by authorizing dealers in raw milk, who maintained tuber-

\* Oliver Wendell Holmes said, "Nature has provided a substantial pair of mammary glands, which have the advantage over the two hemispheres of the most learned professor's brain in compounding a food for babies."



culin-tested herds and met other high standards, to label their products "Grade A," while others, who otherwise met the standards but had to wait for testing, were required to use a "Grade B" label. Naturally, under such a system, it was impossible to defend the continued sale of relatively unsafe milk beyond the time necessary for milk dealers generally to meet the higher standards.

Every consumer, regardless of ability to pay, should have safe, clean milk. Furthermore, competition forces dealers in milk of lower grades to raise their standards. Thus, all of the milk in most markets reaches the sanitary standards set for "Grade A Pasteurized," whether under that designation or some similar one, and grading from the standpoints of health and sanitation loses its importance as a tool for improving safety and sanitary quality. The attempt to introduce factors of questionable health significance, as distinctions between grades, cannot be justified as a means of continuing grading when reasonable standards of sanitary quality have been reached. Consumers have come to recognize the label Grade A Pasteurized or its equivalent as a warranty of the safety of the product within the container on which the label appears.

Grading based on such general qualities as butterfat content will continue to have considerable economic significance, providing that the consuming public is protected against fraudulent labeling. Without official control such grading becomes a farce and a means of defrauding the public. An example of this is the labeling of ordinary milk as "natural vitamin D milk."

The grades commonly used today are:

**GRADE A. *Grade A Raw.*** Milk from cows tuberculin tested and free from brucellosis and other disease, produced and handled by persons free from infection, the bacterial count not to exceed 30,000 per ml. at the time of delivery to the consumer, coming from dairies meeting standards equivalent to those of the milk code recommended by the U. S. Public Health Service. This is a clean milk of questionable safety. It is rapidly being replaced by pasteurized milk.

***Grade A Pasteurized.*** Milk containing at no time more than 200,000 bacteria per ml. and coming from farms that meet all the essential requirements for those producing Grade A raw milk. All milk of this class shall be pasteurized under official supervision and the bacterial count shall not exceed 30,000 per ml. at the time of delivery to the consumer. The trend is toward also setting standards for adequate heat treatment as determined by the phosphatase test and the coliform test, serving the dual purpose of detecting recontamination of pasteurized milk and possible minor flaws in pasteurization.

**CERTIFIED MILK.** Certified milk is produced under the supervision and direction of a medical milk commission. It is fresh, clean and unaltered. It is raw milk of good quality and uniform composition, obtained by cleanly methods from healthy cows. The term "certified milk" was coined by Henry L. Coit of Newark, New Jersey, who in 1892, needing good milk for his own baby, formulated a plan for the production of clean, fresh, good milk under the auspices of a medical milk commission.

Certified milk is a fine ideal which has helped raise the quality of the entire supply. There were 30 farms producing certified milk in 1954, making about 10 million quarts per year, much of which is pasteurized. This represents only about

1/8 of one per cent of the total milk supply; many communities have no certified milk. The economic trend is toward fewer and larger certified dairies. It is not, therefore, a public health problem of any magnitude.

The medical milk commission is appointed by the county medical society; in some places the commission is either organized by or associated with the health department. The commission should include at least five members to look after (a) the sanitation of the dairy, (b) the veterinary supervision of the herd, (c) the medical supervision of the employees, and (d) the chemical and bacteriological supervision of the milk.

The use of the term "certified milk" should be limited to milk produced in accordance with the requirements of the American Association of Medical Milk Commissions.\* The first requisite in the production of certified milk is to enlist the cooperation of a trustworthy dairyman who is willing to enter into a contract with the medical milk commission. In accordance with the terms of this contract, the dairyman binds himself to comply with the specifications set forth and in return his milk is certified. The certificates are the caps for the bottles which are furnished by the commission.

The dairies are subjected to periodic inspections, and the milk to frequent analyses. The cows producing certified milk must be free from tuberculosis, as shown by the tuberculin test and physical examination by a qualified veterinarian, and from brucellosis and all other communicable disease, and from all diseases and conditions whatsoever likely to deteriorate the milk. They must be housed in clean, properly ventilated stables of sanitary construction, and must be kept clean and properly fed and cared for. All persons who come in contact with the milk must exercise scrupulous cleanliness, and must not harbor the germs of typhoid fever, tuberculosis, diphtheria, pathogenic streptococci, or other infections liable to be conveyed to the milk. Milk must be drawn under all precautions necessary to avoid contamination, and must be immediately cooled to 45° F, placed in sterilized bottles, and kept at a temperature between 35° and 45° F until delivered to the consumer. Pure water, as determined by chemical and bacteriological examination, is to be provided for use throughout the dairy farm and dairy. Certified milk should not contain more than 10,000 bacteria per ml., and should not be more than 36 hours old when delivered.

Certified milk is raw milk and, therefore, may convey the infectious agents of disease; in fact, this has happened. Such occasional danger may be guarded against by pasteurization.

**CERTIFIED-PASTEURIZED.** The pasteurization of certified milk is optional. It was established legally in Boston in 1929 and since recognized by the American Association of Medical Milk Commissions. Thus, the cleanest, freshest raw milk obtainable in large cities may be made safe. Standard plate counts of pasteurized certified milk often show no growth and average less than 500 colonies per ml.

**Decomposition of Milk.** Milk spoils in various ways as the result of bacterial growth, the kind of decomposition depending upon the kind of bacteria which predominate. Milk, as a rule, ferments, but sometimes it putrefies. In the former case

\* See annual reports of this Association; *Methods and Standards for the Production of Certified Milk*, adopted by the American Association of Medical Milk Commissions, 1954-55,

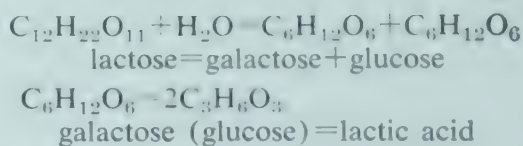


the main change takes place in the carbohydrates; in the latter the proteins are broken down. The fermentation, known as the souring of milk, is accompanied by an acid reaction and a precipitation of the casein. Putrid milk turns alkaline and bitter, owing to the formation of peptones. Sour milk is regarded as the "normal" form of decomposition, because it is the usual change and is not harmful. Putrid milk is believed at times to contain toxic substances; it is at least suspicious.

**SOUR MILK; LACTIC ACID FERMENTATION.** Milk curdles or sours when the soluble caseinogen is precipitated as casein. The caseinogen exists in milk as a complex molecule containing calcium phosphate loosely bound to it; it also contains calcium as part of the molecular complex. The formula may be expressed thus:



The casein is held in solution (colloidal suspension) by the calcium phosphate and other soluble salts of calcium. Any chemical reaction that removes the calcium phosphate from this combination causes a precipitation of the caseinogen as casein. The casein may be precipitated by various substances, such as rennin or acids. In the normal curdling or souring of milk the casein is precipitated by lactic acid produced through the action of bacteria upon lactose. The lactic acid results from hydrolysis of the lactose as follows:



The bacteria usually concerned in the souring of milk are: *Lactobacillus acidophilus*, *L. bifidus*, *L. casei*, *E. coli*, *Streptococcus lactis*, *L. bulgaricus* and a great number of other micro-organisms capable of fermenting sugar with the production of acid. Sour milk, obtained from clean milk, is a beneficial food.

**Sour Milk and Intestinal Flora.** Sour milk contains myriads of lactic acid bacteria. Metchnikoff called attention to the importance of a normal lactic acid flora in the large intestines, which inhibits putrefactive processes and thereby stands guard against "auto-intoxication." He recommended the use of certain bacteria in sour milk, especially *L. bulgaricus*. It is a fallacy, however, to suppose that the flora of the intestines may be influenced through ingestion of these bacteria by the mouth, even when taken in enormous numbers, as in sour milk. A sour milk diet is uncertain in its effects and often disappointing in its results.

Contrary to widespread belief, the bacterial flora of the alimentary tract is not a replica of bacteria ingested. Of the many varieties of micro-organisms gaining entrance into the alimentary tract, few succeed in establishing themselves. The diet of early infancy is rich in carbohydrates in the form of lactose. The *L. bifidus* then establishes itself in the intestines. As the diet changes with age, the colon group of bacteria begins to assert itself, not because these organisms dominate in the diet, but because they, above all others, thrive as well in a medium from which carbohydrates are absent, as in one containing them. *E. coli* and related bacilli constitute nearly 60 per cent of the viable fecal flora.

The number and kinds of bacteria vary in different parts of the digestive tube. The number becomes enormous in the large intestine. It is estimated that about

$3 \times 10^{12}$  are excreted daily by a normal adult. Bacteria supply 46 per cent of the total fecal nitrogen. It has even been questioned whether we could live without intestinal bacteria. Levin, however, found the intestines of a number of Arctic animals sterile. Loeb and Northrup have been able to raise large numbers of banana flies under sterile conditions. These experiments show that the duration of life of these flies varies inversely as the temperature of their environment.

When it was shown that the Bulgarian bacillus cannot be seeded in the intestines because it is not a normal inhabitant of man, in fact does not occur in the feces of Bulgarian peasants, attention was turned toward the closely allied *L. acidophilus* which is a normal inhabitant of the human alimentary tract, especially of children and some adults, where ordinarily it is found in small numbers. It is doubted if they can be "implanted" or increased in numbers by taking them by the mouth. Efforts to implant them are variable, often disappointing, and probably never permanent. Living cultures in milk, reinforced with lactose, as advocated by Cheplin and Rettger, are claimed to relieve constipation and otherwise be beneficial especially by restraining putrefactive processes. However, indican and phenol excretion in the urine continue and may even increase with milk lactose cultures of *L. acidophilus*. Lactose alone is laxative. It is so poorly absorbed from the bowel that it gets into the lower ileum and colon and there modifies the culture medium so that the fermentative bacteria outgrow the putrefactive ones. *The intestinal flora are controlled by diet rather than by bacteria ingested.* Furthermore, the bacteria passed in the feces are not so much those taken in by the mouth as those that grow in the bowel. In order to get the best results it is necessary to take daily about a quart of milk containing no less than 200 million viable acidophilus bacilli per ml., with the addition of lactose. The secret of acidophilic and other lactic acid therapy may not be to emphasize the administration of the microbe, but to regard the intestinal flora as an indication of a corrective and successful regimen.

**PUTRID MILK. Alkaline Putrefaction.** When boiled milk is allowed to stand at room temperature, it gradually acquires an alkaline reaction,\* a bitter taste, and finally turns putrid, yielding a soft, slimy curd. On further standing this curd is peptonized to form a somewhat clear fluid, and if these putrefactive changes are allowed to proceed for a sufficient length of time a semi-transparent liquid is obtained, having no resemblance to milk. In this form of decomposition the main change occurs in the protein constituent of the milk. These putrefactive changes seldom occur; they are undesirable and are believed sometimes to be dangerous, in that toxic substances may be produced. The principal cause of putrefaction in milk is the spore-bearing group of bacilli, belonging to and resembling the hay bacillus and also the anaerobes.

**SLIMY OR ROPY MILK.** Under some circumstances certain mucilaginous substances develop in milk through abnormal fermentation. This occurs mainly in the spring. Slimy milk has been obtained of such viscosity that it could be drawn out into threads 10 feet in length, and of such thinness as to be scarcely visible. In Norway such milk is esteemed a delicacy; in this country, however, it is objectionable. From a health standpoint ropy milk is not injurious unless it is slimy as a result of mucopurulent materials caused by diseased conditions in the mammary

\* Schorer found that such milk becomes less acid but seldom actually alkaline in reaction.



glands. The bacteria which produce ropy milk are widely distributed in nature. Of these *Alcaligenes viscosus* is the commonest organism found in Europe, and a similar organism occurs in this country. *Alcaligenes viscosus* is very hardy; it may find its way into the milk as by the cows wetting their udders and teats in pools of water just before milking, and then become widely diffused. It is sometimes very troublesome, but may be eradicated through cleanliness. It often requires a liberal and repeated use of hypochlorites and steam disinfection. Other organisms producing sliminess in milk are the *Micrococcus freudenreichii*, two forms of streptococci, and certain of the lactic acid bacteria.

**ALCOHOLIC FERMENTATION.** This is an unusual fermentation which sometimes occurs as a result of yeasts, aided in their action by certain species of bacteria. Alcoholic fermentation of milk seldom occurs spontaneously, but may be induced by direct inoculations with certain ferments, such as those employed in the production of kumyss and kefir.

**Kumyss** was originally made from mare's milk; it is now also made from cow's milk by the addition of cane sugar and yeast. **Kefir** is a similar beverage, originating in the Caucasus, where the fermentation is carried out in leather bottles and is started by means of "kefir grains" which contain yeast and various micro-organisms.

**Bitter Milk.** Freshly drawn milk sometimes has a bitter taste; in other instances milk acquires such a taste on standing a few hours. The former is due to improperly feeding the cow with such herbs as lupines, wormwood, raw Swedish turnips, cabbage, etc. The latter case is due to the growth of certain bacteria in the milk after it is drawn. Conn ascribes the power of ruining the taste of freshly drawn milk in a few hours to a micrococcus, while Weigmann thinks a bacillus is responsible. The condition is undesirable, and sometimes causes much trouble for the dairyman, but it has no particular sanitary significance.

**Off Flavors.** Milk sometimes has an off flavor as it comes from the cow. The causes are not always clear. One of the most annoying is called cardboard or metallic taste. The cardboard flavor is believed to be caused by an oxidation reaction which is accelerated in several ways, including exposure of the milk in clear glass bottles to direct sunlight. It develops gradually on standing. It is more common in wintertime and is likely to disappear in the summer season.

**Colored Milk.** Blue milk is usually due to the *Pseudomonas synecyanea*. Such milk is apparently harmless. Red milk may be due to the presence of blood coming from an injury, or acute infection of the udder. Sometimes it results from the feeding of the cow on plants containing red pigment, such as the madder root. A red color may also be produced by the *Bacterium erythrogenes*, *Serratia marcescens* and *sarcinae*. Red milk caused through the agency of bacteria is not known to be harmful.

**Soft Curd Milk.** The milk from some cows produces a much softer curd than that from others. The toughness of the curd is determined by the curd tension. Milk with a curd tension of less than 30 gm. is called soft curd, and that above 30 gm. is hard curd. It is assumed that a soft curd is more readily digested.

Natural soft curd milk is obtained from selected cows. Artificial soft curd milk is made by homogenizing milk between 100° and 104° F at 3,000 pounds pressure. Boiling also softens the curd. A small quantity of blood serum added to milk will do the same. Cows having a pathological condition of the udder secrete a soft curd

milk. It has been learned by experience that selecting cows for the production of soft curd milk generally results in picking out those with diseased udders, so this method is impractical.

*Homogenized milk*, also called viscolized milk, not only has a softer curd but the fat is in a stable emulsion and the cream does not rise on standing. It is palatable and digestible.

**Adulterations of Milk. SKIMMING.** The removal of part or all of the cream and selling the remaining fluid as whole milk is an economic fraud, and has no reference to health, except that the milk is correspondingly lowered in nutritive value. Adding skim milk or condensed milk is a form of tampering difficult to detect.

**WATERING.** The practice of watering is not nearly so frequent as formerly. If the water be pure it must be regarded more as a fraud than a health problem. The addition of water to milk may be detected because it lowers its specific gravity, raises its freezing point, and lowers its index of refraction, its viscosity and its conductivity.

*Alkalis*, such as sodium carbonate or bicarbonate, are occasionally added to milk to reduce its acidity or to improve its taste or to delay curdling. Condensed skim is added to raise the total solids.

**CHEMICAL PRESERVATIVES.** Chemical preservatives, such as borax and boric acid, salicylic acid, benzoic acid and benzoates, potassium bichromate, peroxide of hydrogen, fluorides, formaldehyde, and others, have from time to time been used in milk. The oxidizing preservatives injure the vitamins, and the alkalis camouflage acid fermentation. The practice of adding any chemical preservative to milk meets with the unqualified disapproval of the sanitarian. Almost all countries prohibit the use of such foreign substances. The only proper preservatives for milk are *cleanliness* and *cold*.

**Dirty Milk; The Dirt Test.** Practically all milk contains more or less dirt. For the most part, this dirt consists of cow feces and dust from feed. The presence of dirt may best be determined by filtering a pint of milk through a little disk of absorbent cotton. This produces a stain varying in intensity from a yellowish to a brownish or black spot. A Gooch crucible, a Lorenz apparatus, or simply an ordinary funnel may be used to filter the milk. Warm milk filters much more readily than cold milk. This simple test is one of the practical routine tests used for the administrative control of milk supplies. The intensity of the stain and the amount of deposit upon the cotton is a telltale which appeals strongly to farmers and dairymen, as well as to consumers. It is a good practice to send these disks of cotton, with a letter, to the farmer, showing him the amount of dirt contained in his milk. The disks may be dried and kept with the records of the health office. There is a trend toward the use of sediment testers designed to pump a pint of milk from the bottom of a can as delivered and force it through a standard cotton disk. This is rapid and easy to use.

It should be remembered that milk that has been "clarified" or strained will not show the dirt test. The use of the test may result simply in more effective straining of the milk at the dairy farm.

**Clarification.** Clarification consists of mechanical straining by the use of centrifugal force. Clarifiers of the de Laval type whirl the milk with sufficient force to throw the heavier substances to the circumference of the revolving bowl where they



become attached while the milk serum with its fat and normal solids escape through the central outlet. Milk so treated, therefore, will not deposit a sediment on standing and the value of the dirt test is destroyed. The material adhering to the circumference of the bowl is called *separator slime* and consists of dirt, foreign particles of all sorts, bacteria, pus, blood, mucus, leukocytes, epithelial cells and cell detritus, and a small amount of the substances normally present in milk. Cold clarification is the only acceptable type, for warm clarification tends to break up the dirt into particles more difficult to remove.

The advantages of clarification are that it is more efficient in removing visible dirt than filtration through a strainer. But, it is not a substitute for sanitation, since it does not remove soluble dirt, nor is it a substitute for pasteurization since it does not effectively remove pathogenic bacteria. The merits of the process have often been abused by dealers who have made exaggerated claims and mislead the public with a false sense of security.

Filtration and straining are commonly used in the milk room of the dairy barn, but are also much practiced by the city dairy. The use of single service filters and fabrics should be required and, in plants, filtration should precede pasteurization.

**Number of Bacteria in Milk.** Milk may contain more bacteria than any other known substance; in fact, many more than are found in sewage. Sour milk contains myriads. Mere numbers, however, need not alarm us, for it is the kind that most concerns us. By universal consent, however, milk containing an excessive number of miscellaneous bacteria is not suitable for infant feeding. If milk were a transparent fluid, the enormous overgrowth of micro-organisms which are sometimes present in market milk would be plainly visible to the naked eye.

The bacteria get into the milk from a number of different sources. Some of them are in the milk before it leaves the udder. They may migrate up the milk ducts into the milk cistern; hence, the foremilk contains more than the midmilk or strippings. It is practically impossible to obtain sterile milk directly from the teat in any large quantity. As soon as the milk leaves the teat it receives additional contamination from all objects with which it comes in contact, as the hands, the pail, the dust in the air, etc.

The most important factors to obtain milk with a low bacterial count are: clean and sterilized pails, cans and other utensils; clean dry hands and clean milking machines; healthy cows with clean udders and teats; and the use of the small top milk pail. Experiments have shown that the greatest number of bacteria come from the dirt and dung that fall into the pail during milking and from the pail itself, if not clean and scalded. Milking machines, which are being used in increasing numbers, may contribute many bacteria when carelessly washed, sterilized and stored. To keep the counts low, it is necessary to chill the milk at once and to hold it below 50° F.

It has been repeatedly demonstrated that the rank and file of dairy farmers in their ordinary cow stables can, by the practice of elementary sanitary methods, produce milk which regularly contains less than 10,000 bacteria per ml. This requires not only intelligence but also conscientiousness.

Judged by the number of colonies on Petri plates, the number of bacteria in milk increases every time it is handled or exposed in any way. Separator milk seems to contain more bacteria than the original milk. The same is true of filtered

milk. This is due to the fact that while some of the dirt is taken out, the particles, including clumps of bacteria, are broken up and the bacteria dispersed throughout the fluid, thereby giving more colonies on plate cultures.

Mastitis (garget), or inflammation of the udder, is a common affection of cows, and is associated with streptococci, staphylococci, and colon bacilli, etc. Milk from a gargety udder will contain enormous numbers of micro-organisms.

When milk contains bacteria harmful to man, they almost always get into the milk from human sources, either directly or indirectly. The chief exceptions to this rule are the bovine tubercle bacillus, *Brucella*, bovine hemolytic streptococci, and the virus of foot and mouth disease.

The bacteria in milk are not equally distributed throughout the fluid. There are more bacteria in cream than in the underlying skim milk, particularly in gravity cream. As the cream rises it mechanically carries many of the bacteria along with it, much as a snowstorm sweeps the atmosphere. Milk formulae for infant feeding are often made of top milk, which, however, may contain from five to one hundred times the number of bacteria per ml. found in the whole milk. In 26 samples of milk Anderson found the gravity cream contained about four times as many bacteria as the sediment layer, and about one-third as many as the whole milk. Schorer found that the cream from milk of high bacterial count contained several thousand times as many bacteria as the underlying skim milk.

Formerly, our milk supply contained millions of bacteria per ml. In Washington, in 1908, the average bacterial count of market milk was 22,000,000 per ml. The great reduction is due to sanitary supervision and pasteurization. It is seldom now that raw milk for pasteurization reaches the plant containing over 500,000 bacteria per ml. and most ordinances do not permit over 200,000.

Excessive numbers of bacteria in milk indicate that it is dirty, old or warm. One or any combination of these factors favors a rapid growth and multiplication of the bacteria in milk.

*The phosphatase and coliform tests collectively constitute the best index of safety and the number of bacteria in milk is the best single index we have of its general sanitary character.*

**PATHOGENIC BACTERIA IN MILK.** For the most part, bacteria do not pass a healthy udder. However, we can place no trust in the filtering ability of the mammary gland. It is known that the virus of foot and mouth disease, which is ultra-microscopic, and the organisms causing brucellosis (undulant fever) (*Brucella abortus suis* and *melitensis*), and *Mycrobacterium tuberculosis* (bovis) are frequently found in the milk of infected animals. *E. coli* in milk comes from manure. A milk free from *E. coli* is an especially clean and carefully produced milk; but when large numbers are present, the milk is very dirty or from a herd of cows infected with these organisms.

For the most part, when milk contains bacteria pathogenic for man, the milk is contaminated from human sources. This is almost invariably the case with diphtheria, scarlet fever, septic sore throat and typhoid fever. Occasionally, however, the udder may become infected with bacteria pathogenic for man. For example, *Streptococcus pyogenes* (Group A), the cause of septic sore throat, may get into the udder where it grows and multiplies and may thus infect the milk for a long period. Brooks, in 1939, stated that two outbreaks of scarlet fever in different localities,



eight months apart, were traced to raw milk from a single cow whose udder was shown to be infected with Lancefield Group A streptococci. These bacteria persisted in the udder during a breeding period and the second outbreak occurred soon after the cow freshened. In this case, however, the original infection is introduced from human sources (see page 869). Some hemolytic streptococci ordinarily found in milk are not known to be pathogenic for man. Many of them are of bovine origin or Lancefield Group B.

**Mastitis.** One of the commonest diseases of milch cows is mastitis, sometimes called garget, often caused by injury, and associated with the bacteria of inflammation, especially streptococci, often a hemolytic type and sometimes of human origin. The presence of mastitis may be determined by use of the strip cup or the squirt test, which consists in straining the first three squirts from the udder through black fabric (silk), when flakes of precipitated casein are clearly visible. Veterinarians use deep palpation of the udder to detect indurations of the tissue. Inflammation of the udder also causes a great increase in the number of leukocytes and an increased alkalinity in the milk which may be detected by simple tests, such as the brom thymol blue test.

**Bacteria in Human Milk.** Investigation of the breast milk of one hundred women disclosed streptococci in 49 per cent of the samples (Dudgon and Jewesbury, 1924). Only 2 per cent of these were regarded as an indication of a pathologic process in the breast, although the number of streptococci in milk with a high polymorphonuclear count was greater than in normal milk. *E. coli* and micrococci (staphylococci), especially *Micrococcus pyogenes* var., were found in normal milk from apparently healthy glands. The bacteriology of mother's milk has received scant attention, but it is now plain that it may be significant in the problem of infant feeding.

**The Bacteriostatic Property of Milk.** The bacteriostatic property of milk has been much misunderstood. It is specific and varies in different animals and even in the same animals at different seasons. In some instances it persists for six hours or more. It is destroyed at 75° C for 15 minutes, or between 80° and 90° C for two minutes. At most, the bacteriostatic action is transitory and cannot take the place of cleanliness and ice, but may be taken advantage of by prompt use of fresh milk and in the prompt delivery of uncooled milk to plants for processing and cooling. It is true that bacteria develop more quickly in heated milk than raw milk, provided the raw milk is fresh; it should be remembered, however, that stale milk, even milk that is a day old, no longer possesses this restraining action. The bacteriostatic property, therefore, is ordinarily absent in market milk. Milk contains agglutinins, lysins and other antibodies similar to those found in the blood.

Rosenau and McCoy have shown that, judged by the number of colonies that develop upon agar plates, the bacteria in milk first diminish, then increase in number. This occurs only in raw milk during the first 8 or 12 hours after it is drawn. Although the bacteria seemingly decrease in numbers, they never entirely disappear. After the initial decrease there is a continuous and rapid increase, until the milk contains almost infinite numbers in each milliliter. The power of milk to restrain the development of bacteria lasts from 6 to 24 hours, depending upon the temperature at which the milk is kept. When the milk is kept warm, 37° C, the decrease is pronounced within the first 8 or 10 hours; after this the milk has entirely lost its restraining action. When the milk is kept cool, 15° C, the decrease is less marked.

but more prolonged. They further showed that at least part of this decrease is due to agglutination.

## MILK PRODUCTS

**Adjusted or Standardized Milk.** The addition or subtraction of cream with the object of obtaining a uniform and definite percentage of fat is known as adjusting or standardizing milk. Holstein and Jersey milks are blended so as to adjust the fat content. Not infrequently cream is removed so as to reduce the fat to the minimum legal limit. A more commendable practice is to fortify the fat content by separating the cream from a portion of the milk and adding this to the general supply.

Adjusting and standardizing is a common practice among large milk dealers. Sanitarians have always looked askance upon the practice, for while the addition of cream can hardly be objected to, its subtraction cannot be approved. The process should be limited to mixing whole milks and controlled by the health authorities. In some areas adjustment other than by blending is illegal.

**Reconstructed Milk.** Reconstructed milk is also called remade milk; sometimes "synthetic" milk. A better name is recombined milk, or reconstituted milk, for it consists in combining powdered whole milk or skimmed milk powder, condensed or evaporated whole milk or skimmed milk, with butter, butter oil, or milk fat, and water. The fat is homogenized to form a fine emulsion in the reconstructed milk. If such products are made entirely from milk constituents, they may be labeled "recombined," or "reconstructed" milk, but if any other fat or oil is substituted in whole or in part for milk fat, then the product should be labeled "artificial milk," "milk substitute" or "filled milk." In some states the sale of such products is illegal.

There is a legitimate field for remade milk. Thus, during World War I it became necessary to find a milk supply for the new city of Nitro, West Virginia, with 25,000 and more inhabitants. The city was established in a section unsuited for dairying and no available supply of fresh milk could be found. The Government relieved the emergency by reconstructing milk by homogenizing butter fat, skimmed milk powder and water. Similarly, some areas were supplied with reconstituted milk by dealers during World War II.

*Filled milk* is a compound made up of skimmed milk to which 3 or 4 per cent of coconut oil is added. It is then condensed to approximately one-half its volume. Many states prohibit the sale of filled milk by law.

The importance of sanitary control and proper labeling of such products is obvious.

*Condensed and evaporated milks* are concentrated by partial dehydration. The first really practical method was devised by Gail Borden, of White Plains, New York, who successfully evaporated milk under reduced pressure, and in 1856 obtained a patent for his process.

The *advantages* of total or partial desiccation, whether evaporated, condensed or powdered milk, are manifest. It reduces weight and bulk and saves carrier charges; it improves the keeping quality of a perishable food; and it suppresses the watery environment necessary for microbial activity. There is little danger of these products conveying infection, for they are either made from pasteurized products or steam sterilized. The process of drying permits milk to be produced in parts of the world where it can be made to best advantage. It saves the surplus at the spring



flush. It simplifies the present cumbersome distribution to the householder, and stabilizes the supply for large cities. Transportation difficulties are swept away. Great quantities are made and used. Sanitary control of production, and honest labeling are therefore doubly important.

*Sweetened condensed milk* is heated to about the pasteurizing temperature but is not sterilized, for high temperatures thicken and darken the product. It is preserved with 40 per cent sugar (sucrose). When not produced under sanitary conditions, it may contain many bacteria per milliliter. Condensed milk contains not less than 28 per cent of milk solids and not less than 8 per cent of milk fat (U. S. Government Standard).

*Evaporated milk* is unsweetened and must be processed by heat in order to preserve it; it is therefore sterile, or nearly so. Evaporated milk contains not less than 7.8 per cent of milk fat nor less than 25.5 per cent of milk solids (U. S. Government Standard).

Condensed and evaporated milks may be made from whole milk, skimmed, or partly skimmed milk. These are useful and legitimate products, but they should be labeled as to the grade of milk used, the amount of butter fat, etc. Inspection should be maintained to insure quality and cleanliness. Babies raised on these products are apt to develop scurvy unless given orange juice, tomato juice or other antiscorbutic.

*Dried Milk (Milk Powder)*. Milk may be dried *in vacuo* at moderate temperatures, or on revolving belts or drums in the presence of hot dry air. The presence of the fat has interposed the greatest difficulty to the complete drying of milk. In the Ekenberg process the milk is sprayed under constant pressure on the inner surface of a rotating steam-heated cylinder. The milk is thus dried in partial vacuum at a comparatively low temperature. A more frequently employed process common in the production of cheaper grades consists in spraying the previously concentrated milk on the exterior highly polished surface of revolving steel drums. Here it is almost instantaneously dried at a temperature of 230° F and then scraped off by sharp knife blades. In the Bénévot-de-Neveu process the milk is first concentrated in a vacuum and then sprayed under great pressure into a large drying chamber where the cloud of finely atomized particles is surrounded by a current of hot air, and thereby instantly dried. The result is a powder in which most of the physical and chemical properties of the original milk are retained.

The process has been improved in recent years to such an extent that when milk powder of good quality is mixed with water it makes a product that resembles milk in nearly all essential particulars.

Dried milk powder may be made from skimmed milk, from partly skimmed milk, or from whole milk, rich in cream. The product keeps well, except that the butter fat in powdered whole milk tends to oxidize on protracted storage developing a slightly rancid flavor. It has practically all the nutritive value of the original milk. Vitamins A and B are not materially affected, but the antiscorbutic properties are diminished about one-half. In other words, drying, pasteurizing and age have about the same effect on this vitamin in milk. For general cooking and food purposes, it is about the equal of liquid milk.

Dried milk has all the uses of milk. It is used as a basis of certain proprietary infant foods; it is employed in admixture with cocoa and sugar, with egg powder and sugar as a custard powder, and in various other food combinations. It is exten-

ively used in the baking and confectionery trades. It is convenient in the household and economical so far as waste is concerned.

Babies have been fed on dried milk exclusively with good results, but not all methods of drying have yet been tested. The answer to this question must await a number of years of patient observation. In any case, antiscorbutic accessories, as orange juice, should be used. Dried milk powder makes a good food for growing children and adults.

**Fresh Milk Products.** Cream, butter, buttermilk, ice cream, sour milk, fresh cheese, and other milk products may convey all the infections contained in the original milk from which they are prepared. It is known that tubercle bacilli pass into butter and may live there for months. It has also been demonstrated that infected cream has been the cause of typhoid fever, septic sore throat, diphtheria, scarlet fever, and other milk-borne diseases. Extensive outbreaks of typhoid fever have been traced to fresh or uncured Cheddar cheese and it has been demonstrated that the hemolytic streptococci causing septic sore throat, as well as *Brucella abortus*, will remain viable therein for a month or more. Cheese made experimentally, incorporating cultures of these pathogens, has been shown to contain viable pathogens after many months of storage. Outbreaks of typhoid fever, scarlet fever and other diseases have been traced to ice cream. Cold preserves rather than kills bacteria. Therefore, ice cream may be infected either with the milk or cream from which it is made, or directly from a case or carrier.

Milk products are often made from milk that is left over or otherwise unsalable. This should be controlled by an efficient system of inspection.

The infections in fresh milk products may be guarded against by pasteurization. It is comparatively easy to pasteurize cream, for the reason that it may be heated to a higher temperature than is the case with milk without materially altering its physical properties.

**BUTTER.** Butter is made by churning "gravity" cream or "separator" cream. The cream may be fresh, but is usually ripened, that is, partially sour before it is made into butter. Special cultures of micro-organisms ("starters") are sometimes added to ripen the cream for the purpose of giving the butter a particular flavor.

Butter is usually "scored" in accordance with a score card proposed by Woll in which 45 points are allowed for flavor, 25 for grain (body), 15 for color, 10 for salt, and 5 for packing.

Butter turns acid and rancid in time, owing to the conversion of the fat into fatty acids. Rancid butter may be renovated by washing it with skimmed milk or with water to which bicarbonate of soda or lime is sometimes added to neutralize the acidity. Much butter is made from cream, the acid reaction of which is neutralized with alkalis, the rancid odors and taste blown out with steam, further enzyme action stopped with hydroquinone, and advancing decomposition checked with chlorine or other preservative. Much butter and cream of poor quality are renovated. There is no particular health objection to these processes provided such butter is sold as renovated butter.

Fresh butter contains a great number of micro-organisms (millions per gram). The total bacterial count diminishes with time. There may be a reduction of 85 per cent in two weeks, and 93 per cent in four weeks. Butter may contain tubercle bacilli, typhoid and other pathogenic bacilli. Of 21 samples of market butter ex-



mined in Boston, 2 of them were found to contain tubercle bacilli, being 9.5 per cent of the samples examined. On account of this danger butter should always be made from pasteurized cream and labeled "butter made from pasteurized cream," not "pasteurized butter."

Petri examined 102 samples of butter at Berlin, using 408 animals for inoculation; 16.7 per cent contained tubercle bacilli. Korn found 23.5 per cent of 17 samples of butter at Freiberg to contain tubercle bacilli.

The frequency with which tubercle bacilli are found in butter is shown in a table collected by Swithinbank and Newman. Of 498 samples tested from different sources, 76, or 15.2 per cent, contained tubercle bacilli.

Schroder and Cotton have found that living tubercle bacilli will retain their infective properties for at least 160 days in salted butter when kept without ice in a house cellar.

Butter may also convey typhoid bacilli and other pathogenic micro-organisms.

*Oleomargarine* consists of a mixture of edible animal and vegetable fats churned with milk. Since all of the ingredients are in themselves useful foods, the wholesomeness and nutritive value of the finished product is beyond question. Oleomargarine consisting exclusively of vegetable oils churned with skimmed milk is deficient in the growth-producing vitamins. The principal deficiency is in vitamin A. Since early in World War II manufacturers of oleomargarine have been adding about 9,000 units of vitamin A per pound, which is equivalent to the vitamin A content of butter. The better grade of oleomargarine also contains some milk fat.

Objections to the manufacture and sale of oleomargarine are based rather on the possibility of fraudulent substitution for butter than on nutritive or sanitary considerations. In the United States, oleomargarine has been an object of federal taxation, and its manufacture has been subject to supervision by the Bureau of Internal Revenue. A tax of 10 cents per pound was imposed on oleomargarine which is artificially colored to resemble butter and a tax of one-fourth cent per pound on the uncolored product. During the fiscal year ended June 30, 1924, 229,031,000 pounds of oleomargarine were manufactured, of which about 44 per cent contained no animal fat. In 1954, the total output of oleomargarine was 1,364,339,000 pounds, of which about 99 per cent was made exclusively from vegetable oils. In many sections of the country, the sale of colored oleomargarine is prohibited either directly or by excessive tax. The federal tax on colored oleomargarine has been reduced.

Oleomargarine containing fats derived from the carcasses of cattle, sheep, swine and goats is a meat food product. It is, therefore, subject to Federal Meat Inspection. This inspection insures the use of pure and wholesome materials and the maintenance of cleanliness and sanitary conditions in the establishment. Only animal fats from "U. S. Inspected and Passed" carcasses may be used. Oleomargarine prepared exclusively from vegetable fats is not subject to federal inspection. Pasteurization of milk and other dairy products used is required in all establishments operating under Federal Meat Inspection and is regularly practiced in establishments preparing oleomargarine from vegetable oils. It will be evident, therefore, that the possibility of disseminating disease through oleomargarine is exceedingly remote.

**CHEESE.** Cheese is one of the oldest of the milk products. There are many varieties of cheese, of which Cheddar type is most common. It is a concentrated and valuable food. Roughly speaking, many varieties contain about one-third fat, one-

fourth protein and one-third water. Cheese varies in its richness in calcium depending on the mode of manufacture. In cheese produced from sour milk, much of the calcium is lost in whey. This is not the case in cheese prepared with rennin.

Although pathogens in cheese will become devitalized after long storage at temperatures above zero degrees centigrade, pasteurization offers greater protection. Higher temperatures result in more rapid destruction of pathogens. The cheese should be made from pasteurized products or the cheese should be pasteurized, as in so-called "processed cheese."

### DISEASES SPREAD BY MILK

The disease conveyed through milk are: tuberculosis, typhoid and paratyphoid fevers, gastro-enteritis or food poisoning, diphtheria, streptococcal infections (scarlet fever and septic sore throat), brucellosis (undulant fever), foot and mouth disease, Q fever and milk sickness; also some of the summer complaints of children, and the diarrheal and dysenteric diseases of adults, which are occasionally referable to infected milk. Infantile paralysis may be rarely milk-borne.

Milk becomes infected from human sources, usually on the farm, sometimes at the milk plant, occasionally in transportation, and rarely in the household of the consumer. Sometimes the milk becomes infected as a result of disease of the animal, as in the case of bovine tuberculosis, brucellosis, foot and mouth disease, and Q fever. Furthermore, cows' udders may become infected with human pathogens, particularly Lancefield Group A hemolytic streptococci.

Bussey and Kober in 1895, Baker in 1896, Freeman in 1896, Hart in 1897, Caroe in 1898, Schleghtendal in 1900, and Trask in 1909 reported over 700 milk-borne outbreaks of disease, of which 179 occurred in the United States. Armstrong and Parran (1927) have tabulated additional instances. Experience has shown that many milk-borne outbreaks go unrecognized or unreported. Notwithstanding the great progress made in improving the safety of milk supplies, in 1945 there were 29 milk-borne epidemics reported in the United States which caused 2,161 cases of disease with 17 deaths.

Milk-borne outbreaks of disease are nearly always due to raw milk; often milk of good quality, even certified milk. A few outbreaks have been traced to milk labeled pasteurized which either has not been pasteurized at all, was grossly under-pasteurized or was contaminated after pasteurization with raw milk or with pathogens from cases or carriers. There is no record of a milk-borne outbreak attributable to properly pasteurized milk.

**Tuberculosis.** Milk is the chief vehicle for the conveyance of bovine tubercle bacilli from cow to man. They get into milk either directly as a result of tuberculosis of the udder, which occurs in from 1 to 2 per cent of all tuberculous cows, or indirectly through cow manure. In the latter case the tubercle bacilli are coughed up, swallowed, and passed in the feces. Practically all market milk contains cow feces. Tuberculosis in cattle is still prevalent in some countries. This situation has definitely improved in the United States owing to tuberculin testing of herds on an area basis with the purchase and slaughter of reacting animals, the disinfection of premises and the establishment of accredited herds. The "milk" from a tuberculous udder, when examined under the microscope, may contain as many tubercle bacilli



Table 22-2. Reported outbreaks of milk-borne disease in the United States

Disease and Year	Total Cases Reported	Number of Cases Traced to Milk	Cases Traced to Milk, Per Cent	Number of Outbreaks Traced to Milk
<b>Typhoid fever</b>				
1907-1914	23,482	2,215	9.4	50
1915-1924	45,261	1,486	3.3	53
1925-1934	298,929	4,851	1.6	283
1935-1944	114,415	1,410	1.2	114
1945-1949	18,778	154	0.8	9
1950-1954	11,374	2	<0.1	1
Total	512,239	10,118	2.0	510
<b>Streptococcal sore throat</b>				
1907-1914	70,569 *	2,747 *	3.9	10
1915-1924	261,649	1,532	0.6	21
1925-1934	2,005,092	10,430	0.5	103
1935-1944	2,065,663	7,692	0.4	83
1945-1949	474,348	768	0.2	4
1950-1954	499,427 †	102 †	<0.1	2
Total	5,376,748	23,271	0.4	223
<b>Diphtheria</b>				
1907-1914	69,646	131	0.20	5
1915-1924	196,645	61	0.03	3
1925-1934	766,455	151	0.02	11
1935-1944	231,085	92	0.04	4
1945-1949	65,007	53	0.09	1
1950-1954	17,135	0	0.00	0
Total	1,345,973	488	0.04	24

\* Scarlet fever only. Septic sore throat not reported until 1915.

† Beginning in 1951 scarlet fever cases were included as streptococcal sore throat.

as are ordinarily found in tuberculous sputum. The milk from a tuberculous udder of one cow may contain sufficient bacilli seriously to infect the mixed milk of 25 or 30 cows. In one case Ostertag found that 0.001 ml. of the secretion from a tuberculous udder was sufficient to cause tuberculosis in a guinea pig. In such a case a child would receive myriads in a gill.

Tonney examined the market milk of Chicago in 1910 for the presence of tubercle bacilli. In 10.5 per cent of 144 samples of raw milk he found tubercle bacilli in sufficient numbers to infect guinea pigs. Of 19 samples of pasteurized milk examined, none contained tubercle bacilli.

Hess in 1909 examined 107 samples of market milk in New York City, with the result that 17 of them, or 16 per cent, were found to contain tubercle bacilli.

Anderson examined 223 samples taken in the city of Washington, and reported 16, or 6.72 per cent, as positive. The tests made by the Bureau of Animal Industry of the milk in Washington disclosed 7.7 per cent infected. Goler reports about 5 per cent of the milk supply of Rochester, New York, infected.

To sum up, we have evidence from four typical American cities. Live tubercle bacilli have not been disclosed in pasteurized milk. A total of 551 samples of raw milk have been examined, in which tubercle bacilli were found in 46, making a percentage of 8.3. This may be taken as representative for the entire country at that time. The situation is improving with many herds accredited free of tuberculosis and much of the market milk pasteurized.

Delépine (1914) reports that the mixed milk of Manchester, England, collected at railway stations or other places than the farm, contained tubercle bacilli in samples examined in the following inclusive periods:

	<i>Per Cent</i>
1897-1899 . . . . .	17.2
1900-1904 . . . . .	10.3
1905-1909 . . . . .	6.8
1910-1913 . . . . .	9.0

It is believed that the figures were an underestimate, for the methods used in the laboratory were not sufficiently delicate to detect a few tubercle bacilli in milk. Unless these micro-organisms are present in considerable numbers, they are apt to escape detection. In any event, it is clear that the raw market milk heretofore furnished large cities and most small towns often contained tubercle bacilli.

Mohler, Washburn and Doane found that tubercle bacilli remained viable in cheese 220 days old. In these experiments the cheese was purposely infected and fed or inoculated into guinea pigs at various times. Tubercle bacilli are frequently found in butter and other milk products, but only if the milk or cream of which they are made has not been pasteurized.

The relation of bovine tuberculosis to man is considered on page 145.

**Typhoid Fever.** Of milk-borne epidemics, typhoid fever takes the lead. Between 1907 and 1954, 510 outbreaks of typhoid fever were recorded in the United States. Typhoid bacilli may swarm in milk without altering its taste, odor or appearance. In Washington, 10 per cent of all the cases of typhoid fever during the years 1907 to 1910 were traced to milk. Despite the decline in the number of cases, the percentage of cases due to infected milk remains relatively high. Nearly all outbreaks occur on raw milk routes. The milk may become infected by a convalescent, a carrier or a missed case. The hazard varies with the level of endemic prevalence in the milk production area.

Typhoid fever has also been traced to cream, ice cream, and other milk products (see typhoid fever, page 198).

Milk-borne outbreaks of *paratyphoid fever* have been described by Levine and Elbersen (1916), Williams (1925), and others (see salmonellosis, page 207).

**Streptococcal Sore Throat (Scarlet Fever and Septic Sore Throat).** For many years outbreaks of streptococcal sore throat have been reported either as scarlet fever or septic sore throat, the diagnosis depending largely upon whether or not a majority of cases did or did not show desquamation. Furthermore, the attempt to identify the etiologic agent by careful cultural methods has caused further confusion. Now there is quite general agreement that this is one disease caused by hemolytic streptococci of Group A (Lancefield) as determined by serological test (see page 13).

Milk-borne outbreaks of streptococcal sore throat are sometimes extensive and serious. This is especially true when Group A streptococci establish themselves in the milk-secreting alveoli of a cow's udder.

In the cow's udder, the Group A streptococcus from a suppurating wound or an infected throat of a milker establishes itself and produces a form of mastitis. The organism has been demonstrated to persist in the udder of an infected cow during



a dry period and the milk to cause a second outbreak when the cow is freshened. In many outbreaks the human pathogens gain access to the cow's udder through the medium of teat injuries treated by a herdsman with a streptococcal sore throat. In one instance, such a herdsman admitted putting the thread in his mouth to knot the end before sewing up the teat torn on a barbed wire fence. It is believed that another avenue is through the medium of teat tubes or dialators placed in the mouths of persons with streptococcal sore throats as the only supposedly clean place they can put them while preparing to insert them in the cow's teat. Such tubes are used to keep the teat canal open for milking in case of a local infection of the membrane of the teat canal tending to close it.

Another known avenue for the transmission of streptococcal sore throat from a human to others is through the direct introduction of Group A streptococci in milk. In one outbreak in New York State, in which no infection could be found in the cows nor Group A streptococci in milk drawn aseptically, a milker with a suppurating wound on his ankle was observed to readjust the bandage on his wound while changing his shoes for boots immediately before starting to milk by hand. This made a direct avenue for organisms in the pus to get into the milk. In another outbreak of streptococcal sore throat traced to hand-separated raw cream, the two cows producing the milk were given a clean bill of health but a woman with a sore throat placed the milk in open cans to let the cream rise and later removed the cream. It was evident that she introduced pathogens under conditions conducive to growth.

The *Boston outbreak*, in 1911, was characterized by its extraordinary virulence and comparative immunity of children, and high mortality among the aged and infirm. In this outbreak there were over 2,000 cases with about 48 deaths. One of the features of special interest was that the milk incriminated had always been a particularly clean, fresh and satisfactory supply. It was obtained from tuberculin-tested cows under veterinary supervision, and the milk itself subjected to frequent chemical and bacteriological tests. The milk was bottled at the dairy, the bottles were sterilized, and many extra precautions were taken to insure its cleanliness. For 28 years not a breath of suspicion was attached to this milk until this catastrophe occurred. It emphasizes the lesson that raw milk is apt to be dangerous milk, and our only protection against these particular dangers is through pasteurization.

Another instructive outbreak, reported by Benson and Sears (1923), occurred in Portland, Oregon, March 24 to 31, 1922. In this epidemic there were 487 cases and 22 deaths. "Almost all of the cases and all but one of the deaths occurred among people who had drunk raw milk from one dairy which had been rated as one of the best in the city." This is the common story.

**Diphtheria.** Diphtheria bacilli in milk practically always come from human sources, either cases or carriers. In a few rare instances ulcers upon the teat of the cow have become infected with diphtheria, and the bacilli thus transferred to the milk. Such an occurrence, however, is unusual. As a rule, diphtheria outbreaks caused by infected milk are more limited both as to numbers and area than milk borne outbreaks of typhoid or scarlet fever (see diphtheria, page 92). Twenty four outbreaks of diphtheria were recorded in the United States between 1907 and 1948. Many milk-borne outbreaks are not disclosed.

**Milk Sickness.** Milk sickness is an acute nonfebrile disease due to the ingestion of milk, milk products, or the flesh of animals suffering from a disease known as

rembles. The disease is characterized by great depression, persistent vomiting, obstinate constipation and high mortality. The picture is that of a poisoning rather than an infection.

Milk sickness is primarily a disease of cattle, secondarily of man. In cattle it is called slows or trembles, and formerly was prevalent in the central part of the United States. The pioneers suffered severely in winning the West. Nancy Hanks, the mother of Lincoln, died from the disease in 1818 after an illness of a week. As forests are cleared and pastures fenced the disease becomes less frequent.

Marsh, in 1926, studied the rayless goldenrod, *Aplopappus heterophyllus*, and concludes that milk sickness is a poisoning due to this plant. Two species are toxic. The white snake root, a poisonous weed, is also responsible. Marsh produced trembles or alkali disease in horses, cattle and sheep by feeding sufficient quantities of the rayless goldenrod. The toxic principle, tremetol, is excreted in the milk, and calves and lambs may be poisoned in this manner. Stock eat this weed only where there is little good forage. The obvious remedy is to see that the animals are well fed. It is entirely practical to dig out the weed in fenced pastures. Knight (1935) describes a case in North Carolina due to white snake root.

**Undulant Fever (Brucellosis).** Brucellosis in milking animals, particularly cows and goats, is commonly called contagious abortion or Bang's disease. The principal manifestation is abortion. The disease spreads rapidly among susceptible animals and constitutes an economic problem. The specific organism is *Brucella abortus* in cows, *Brucella suis* in swine and *Brucella melitensis* in goats. The presence of the organism has been demonstrated in the milk of infected animals by agglutination of the milk serum and by inoculation of guinea pigs.

The organism may be transmitted to man by ingestion of the raw milk of infected animals or by direct contact with such animals. The discharges of infected animals at the time of parturition play an active role in the spread of the disease among animals and human attendants (see brucellosis, page 523).

**Foot and Mouth Disease.** Foot and mouth disease is an infection primarily of cattle and secondarily of man. It is caused by a filtrable virus, and is noteworthy for being the first ultramicroscopic virus of animals to be discovered by Löffler and Frosch in 1898. The infection may be transmitted to man through the ingestion of raw milk, buttermilk, cheese or whey from diseased cows (see page 532).

**Acute Gastro-enteritis.** Milk may occasionally be involved in food poisoning due to contamination with staphylococci or *Salmonella*. It may be the vehicle of dissemination of *Salmonella* infections (see page 216) and *Shigella* infections (see page 224). In the United States, the use of dirty bacteria-laden milk without pasteurization or boiling was formerly one of the chief causes of infant mortality due to summer diarrheas. The improvement in the milk supply has probably been the most important factor in the decrease in infant mortality in recent years.

**Q Fever.** When Q fever was discovered in the metropolitan area of Los Angeles in 1947, extensive epidemiologic studies were undertaken to determine the source of human infection with the disease. Studies were carried out by the National Institutes of Health in cooperation with the California State Department of Health and the Department of Agriculture and by the Los Angeles city and county health departments. Results are reported by Bell and others (1950). They concluded that the most frequent and by far the most important source of human infection is local



dairy cows, their very young calves and some of their raw products, particularly raw milk and hides. The persons most apt to have been infected were those who used raw milk in their households, those whose residence had been located near a dairy or livestock yard, those who had worked in industries handling hides of recently killed dairy cows and young calves, i.e., employees in dairies, in meat packing plants, and fat rendering plants, and employees handling the raw products of such animals, i.e., employees of creameries and hide plants. The causative agent, *Coxiella burneti*, was repeatedly demonstrated in the milk of dairy cows by Huebner and others (1948). It was further shown that commercial pasteurization essentially reduced but did not entirely eliminate the infection from the milk (Huebner and others, 1949) (see Q fever, page 440).

**Erythema Arthriticum Epidemicum or Haverhill Fever.** This clinical syndrome was described in a small but explosive milk-borne outbreak which occurred in the restricted area of Haverhill, Massachusetts, in 1926. The etiologic agent was identified as *Streptobacillus moniliformis*. Clinically the disease was indistinguishable from rat-bite fever due to *Spirillum minus*.

**Infantile Paralysis.** In the past 35 years three small focal outbreaks of poliomyelitis have been reported where the vehicle of distribution seemed to be a milk supply. In two of these, one in Spring Valley, N. Y., reported by Dingman (1916), and one in Cortland, N. Y., reported by Knapp and others (1926) a case of acute poliomyelitis was found on the farm supplying the milk. In the third, and somewhat larger outbreak described by Aycock, at Broadstairs, England, there were 62 cases. Investigation disclosed that practically all of the cases among the residents of Broadstairs were supplied with milk from the same dealer, and the evidence suggested that contamination of only one grade of his milk, which came from a single farm, was responsible for the epidemic.\* In two additional outbreaks, milk has been suspected of being the vehicle of dissemination (Goldstein and others, 1946; Matthews, 1949). The experiments of Lawson and Melnick (1947) on determination of the thermal death points of some mouse-adapted strains of poliomyelitis virus opened up the possibility of survival of the virus even in pasteurized milk. However, with the possible exception of the incidents noted above, in spite of many investigations, conclusive epidemiological evidence has not been presented to indicate that either raw or pasteurized milk is a vehicle for dissemination of poliomyelitis virus.

### SANITARY CONTROL

**Tests.** The objective of control is to give the public safe, clean milk of good quality. The most direct way to measure accomplishments is by making bacteriological, biochemical and chemical tests on surprise samples of the finished products as offered for consumption. Examination of samples of pasteurized milk, cream and milk products by the phosphatase test will indicate the adequacy of the heat treatment. Although the phosphatase test will show recontamination with as little as 0.1 per cent of raw milk, as by leakage, further examination by making a coliform count will show even more slight contamination with raw milk or from ineffective sterilization of containers. Although it is possible that some heat-resistant strain of coliform organism may be encountered, experience with large numbers of tests has shown that such organisms are rarely encountered in practice. The coliform test of

\* The prolonged and careful investigation of the Ministry of Health was not in favor of this assumption, but traced a chain of personal contact between a number of cases in the epidemic (see Annual Report of the Chief Medical Officer of the Ministry of Health for 1927, H.M.S.O., London, 1927, page 92).

pasteurized milk is a good index of possible failures in pasteurization or, more generally, of recontamination after pasteurization.

Bacteria counts on pasteurized milk, cream or milk products alone are of limited value. There is no assurance that low count milk is free from pathogens. However, used in conjunction with the phosphatase and coliform tests, the standard plate count and direct microscopic count give additional information as to the care that has been exercised in the handling of the milk, including refrigeration. Certain field tests, such as the rapid phosphatase test and the reazurin or methylene blue tests, may be used to advantage as screening tests under certain circumstances.

The weaknesses of control by testing the final product are possible sample errors and the fact that, even with the most profuse sampling, only a small portion of the total quantity consumed can be examined. As examples of sampling errors, we have the delivery of samples at the health department office or laboratory permitting selection by interested parties, the collection of samples invariably on the same day of the week, thus opening the way for carelessness the other six days, and the practice of always taking quart samples, which eliminates the possibility of discovering plant operating faults that may occur only when containers of other sizes are being bottled.

The discerning use of the results of field and laboratory tests supplemented by inspection, which also has its strong as well as its weak points, is most likely to result in effective control.

**Inspection.** An efficient inspection service is a preventive measure that strikes at the root of the milk problem. A good inspection service is expensive, but is worth its cost in providing cleaner and better milk.

The inspection of pasteurizing plants is a primary responsibility of the control official. While the laboratory tests of the finished product will indicate weaknesses or failures in plant operation, inspection also may uncover other evidence missed by tests of the final product, because the samples taken represent a very small proportion of the total product. Similarly, inspection has the weakness that the inspector, at best, only a small portion of the total operation. Furthermore, the operator is likely to be on good behavior knowing the inspector is in the plant, and in some instances the inspector may not be alert enough to catch the significance of what is going on before his eyes.

Plant inspection should include the careful examination and auditing of the recording thermometer charts on file, the determination of the accuracy of recording and indicating thermometers and the checking of controls, valves, milk pumps and other parts of equipment performing important functions in insuring pasteurization. Furthermore, such inspections should be so made as to determine the effectiveness of the cleansing and bactericidal treatment of containers and equipment.

Dairy farm inspections are made so infrequently and at such times of the day as to be of little assistance in determining the routine care exercised in the milk handling operations and in the cleansing and bactericidal treatment of utensils. They are of value in determining that favorable conditions for the production of clean milk exist on the farm and offer an opportunity to the alert sanitarian to get acquainted with the dairyman in order to sell his educational program and to secure the dairyman's cooperation in the production of clean milk. Receipt of a copy of the inspection report should be acknowledged by the dairyman's signature and be posted



in the milk house. A satisfactory inspection report may well be endorsed by the inspector so as to constitute a permit for the delivery of milk to an approved plant or receiving station. There is little to be gained in the protection of the public health by regimenting dairymen into providing expensive plants and equipment of any special design. Certain things are necessary to economical operation and generally will be provided for that reason.

As in the sanitary control of pasteurizing plants, most can be accomplished in securing the delivery of good, clean milk consistently from dairy farms by testing the milk periodically as delivered at the receiving platforms of pasteurizing plants or receiving stations and following up all unsatisfactory results promptly to determine and eliminate the conditions on the farms which caused the unsatisfactory results. The direct microscopic count lends itself best to this type of work when used in conjunction with the sediment test. *Reduction* tests are not as informative as the direct microscopic count but may be used to advantage if properly interpreted. The reazurin test is to be preferred to the methylene blue test, particularly because the results may be obtained in not more than two hours instead of a possible eight hours.

Some health authorities require the dairyman to employ a veterinarian to make an annual physical examination of all cows producing milk. This frequently is done by deep palpation of the empty udder to detect the pressure of scar tissue resulting from mastitis. Lack of symmetry in the udder may be an indication of infection. Generally a test such as the brom thymol blue test for alkalinity is applied to a sample of milk from each quarter to confirm the findings. The results must be interpreted carefully as factors other than mastitis may cause alkalinity. However, such things are likely to affect all quarters rather than only one of four.

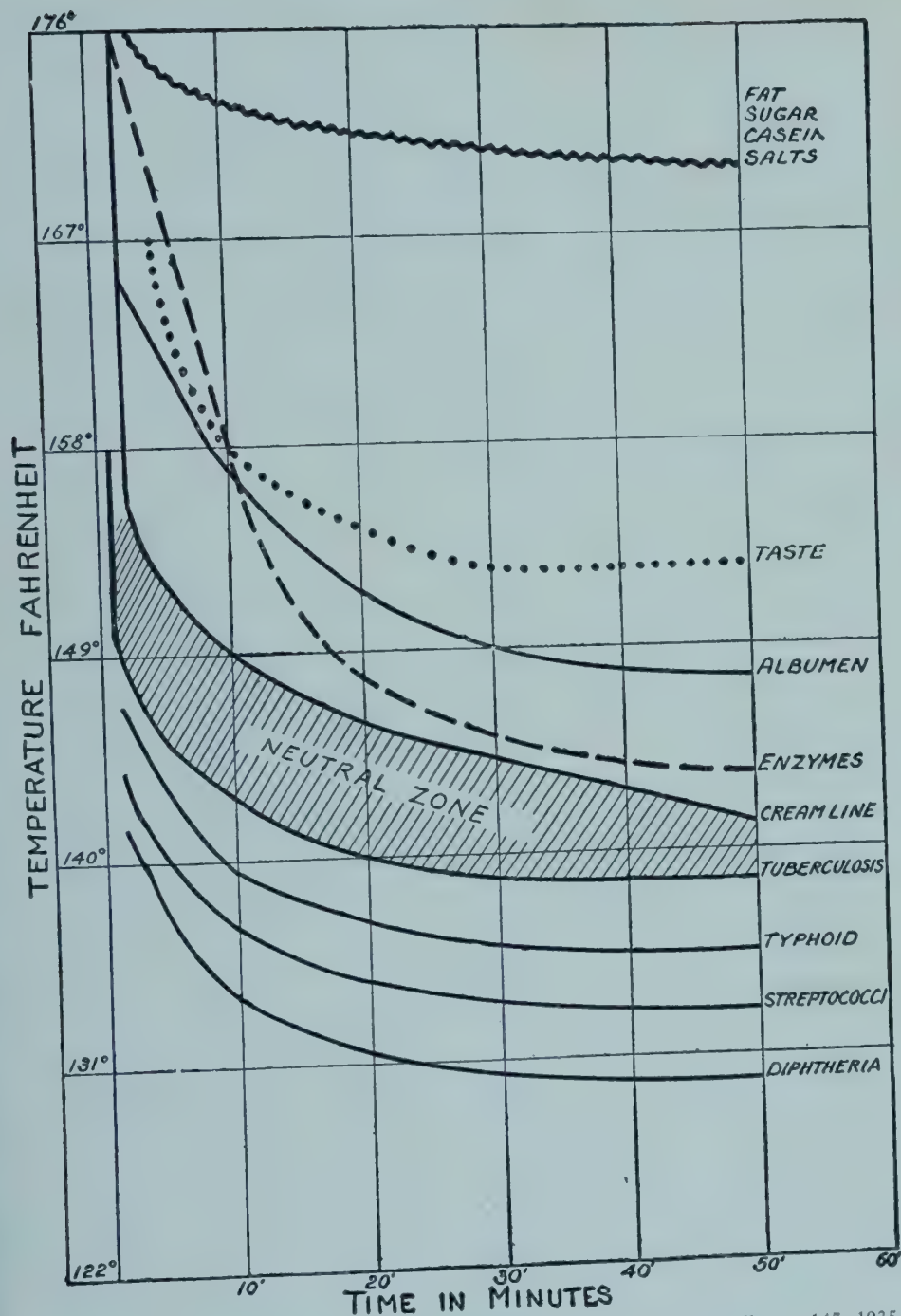
The sanitary inspector cannot prevent occasional unsanitary conditions. The veterinarian often cannot prevent the occasional infection of milk from cattle diseases. The medical inspector cannot prevent the infection of milk from human sources. There is a safeguard to prevent milk-borne infections and epidemics—pasteurization.

Inspection brings us cleaner, fresher, better and safer milk, but not necessarily safe milk. The limitations of inspection are taken care of by pasteurization.

**Pasteurization.** Pasteurization consists in heating milk to a temperature below that of boiling, holding it at that temperature for a definite time, and then chilling it rapidly. The time and temperature of pasteurization are designed to be sufficient to kill the harmful micro-organisms with the least possible effect upon the milk itself.

Pasteurization is a preventive measure of public health importance. It should be defined legally in the sanitary code so that milk labeled "pasteurized" but which has been processed by improper or incomplete methods may be prosecuted as misbranded. The heat of pasteurization does not alter the taste, appearance or digestibility of milk unfavorably, and does not appreciably diminish its food value except that there may be a diminution of its antiscorbutic property, which in any case should be offset by the use of orange juice or tomato juice. In fact, pasteurization tends to make the curds softer and in this way perhaps easier to digest.

**TIME AND TEMPERATURE.** It has been abundantly demonstrated that heating milk to 140° F. (60° C.) for 20 minutes is sufficient to kill the bacilli of tuberculosis, typhoid fever, paratyphoid fevers, dysenteries and diphtheria, the streptococci



From U. S. Pub. Health Bull., no. 147, 1925.

Fig. 22-1. Time and temperature for pasteurization in the neutral zone which is above the thermal death curves for the pathogenic micro-organisms with minimal injury to the milk.

scarlet fever and septic sore throat, the *Brucella* organisms, the virus of foot and mouth disease and all other nonspore-bearing organisms causing milk-borne infections that are of concern to man.

Temperature and time are both factors in the destruction of pathogens as shown in Figure 22-1. This is a presentation of North's curves. The portion above 160° F for less than two minutes of the thermal death curves for pathogens is in need of further exploration.



The commonly accepted definition of pasteurization is that of the United States Public Health Service Milk Ordinance which reads: "The terms 'pasteurization,' 'pasteurized,' and similar terms shall be taken to refer to the process of heating every particle of milk or milk products to at least 143° F, and holding continuously at such temperature for at least 30 minutes, or at least 161° F, and holding at such temperature continuously for at least 15 seconds, in approved and properly operated equipment. . . ." From the standpoint of safety, any time and temperature combination that lies on or above and to the right of the upper line of demarkation of the neutral zone shown in Figure 22-1 should be satisfactory for pasteurization. For administrative purposes the two time-temperature combinations included in the definition have been selected as the standard. An ample factor of safety is provided as indicated by the portion marked "neutral zone." Heat treatment above this level will affect the creaming properties of the milk.

The effectiveness of heat treatment at 143° F for 30 minutes and at 161° F for 15 seconds in destroying pathogens has been demonstrated by laboratory tests, by the pasteurization in test installations of commercial equipment of milk to which pathogens had been added, and by chance occurrences in which portions of milk supplies consumed raw caused outbreaks and pasteurized portions of the same supplies of mixed milk caused no disease among consumers.

As the result of many years of extensive experience with commercial pasteurization, confirmed by laboratory researches as by North and others (1925) it has been demonstrated that a temperature of 142° to 145° F, with a holding period of 30 minutes, serves the purpose of protecting the public health and preserving the integrity of the milk. Later research showed that by subjecting every particle of milk to 160° F or more for not less than 15 seconds in approved equipment gave equivalent results. Pasteurizing machinery is not foolproof, and even the best designed apparatus must be operated with intelligent watchfulness. The thermoregulator should be responsive, the thermometers accurate and frequently standardized, for they are apt to be injured by the steam used in cleaning. The process should be done under official supervision. Automatic records of the temperature and time should be kept for each run.

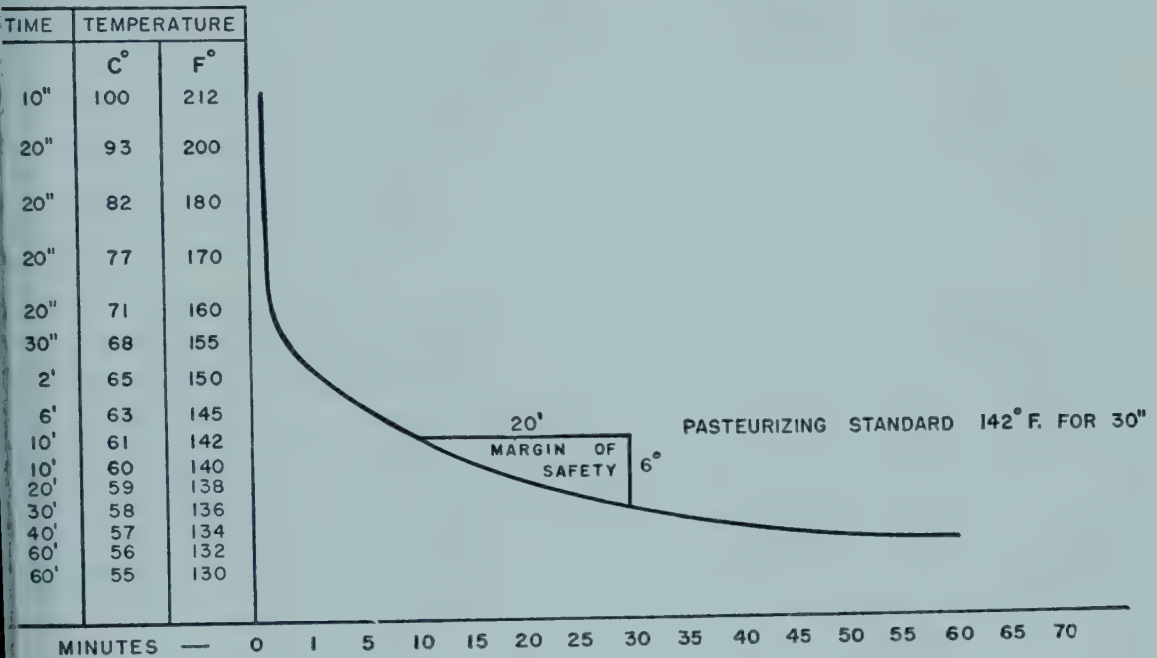
**ADVANTAGES AND DISADVANTAGES.** Pasteurization prevents sickness and saves lives. Pasteurization is not ideal, but only an expedient. It is advocated because milk is likely to convey the viruses of a number of diseases harmful to man. Pasteurization effectively prevents this hazard. It implies precaution, protection and prevention. It is the best insurance both for the industry and the consumer, and the simplest, cheapest, least objectionable and most trustworthy method of rendering infected milk safe. Next to water purification, pasteurization is the most important single preventive measure in the field of sanitation.

Pasteurization does not claim to replace sanitation and common decency. It cannot atone for filth and should not be used as a redemption process. Stale, weak and dirty milk is still stale, weak and dirty after it has been pasteurized. A pure milk is better than a purified milk. However, no one should drink raw milk that cannot be guaranteed by the health officer as safe and free from danger. Even certified milk or milk of equally high character is only reasonably safe without pasteurization. Less than one per cent of all the milk found upon the market is certified. Therefore, raw milk of this honor class is not a public health problem of any magnitude, although

It has been responsible for outbreaks of diphtheria, scarlet fever and other diseases. There is no authentic record of any milk-borne epidemic caused by properly pasteurized milk.

It is sometimes alleged that pasteurization destroys nature's danger signal, souring. Milk pasteurized at the temperatures recommended ( $142^{\circ}$ - $145^{\circ}$  F) sours as a result of lactic acid fermentation just as raw milk does, although somewhat more

#### TUBERCLE BACILLUS KILLED



(NORTH - PARK - 1926)

From Am. J. Hyg., 7:147, 1927.

Fig. 22-2. Thermal death curve of tubercle bacillus.

lowly. Nature has no danger signal for infected milk. Milk may be teeming with typhoid bacilli and other pathogenic micro-organisms without its taste, odor or appearance being changed.

One objection to pasteurization has always been the claim that it will put back the cause of clean milk and good dairy methods, because pasteurization will make cleanliness unnecessary and will put carelessness at a premium. Experience has proven the fallacy of this argument; in fact, the general milk supply of large cities has been materially improved despite pasteurization.

Pasteurization is not proposed as a substitute for, but as an adjunct to, inspection. Inspection gives us cleaner and better, but not necessarily safe milk. Inspectors cannot be present all the time, and furthermore, even if they were Pasteurs, they could not see missed cases and carriers. Pasteurization destroys the dangers inspection cannot see. The combination of inspection and pasteurization corresponds in all respects to the modern principles of furnishing a safe water supply to a large city. The watershed, through inspection, is kept as clean as practicable, but the water is filtered or chlorinated to protect the consumer.

There can be no more objection to the heating of milk for the use of adults or children above the age of one year than there is to the cooking of meat. Infants



should receive breast milk. There is no adequate substitute. When this is not possible, they should have the best and freshest cow's milk that can be obtained. Whether such milk is to be pasteurized, modified, boiled or otherwise treated rests with the pediatrician. Pasteurization has the well-nigh unanimous endorsement of sanitarians and pediatricians.

**The Effects of Heat upon Milk.** The changes produced in milk by heat depend upon the degree of heat, the length of time of exposure, the access of oxygen, the pH and other factors. Milk heated to 145° F for 30 minutes does not undergo any appreciable physical or chemical change. Heat above 145° F for any length of time affects the creaming ability and the properties as exposure increases. The boiling of milk, however, produces pronounced changes. In the main, these consist of a partial denaturing of the proteins and other complex nitrogenous derivatives; diminution of the organic phosphorus and an increase of inorganic phosphorus; changes of form of the calcium, phosphorus and magnesium salts; expulsion of the greater part of the carbon dioxide; caramelization or burning of a certain portion of the milk sugar, causing the brownish color; partial disarrangement of the normal emulsion, and coalescence of some of the fat globules; coagulation of the serum albumin, which begins at 75° C; the ferments are killed; vitamin C is reduced 20 to 50 per cent; vitamins A and B<sub>2</sub> are not affected.

Boiled milk has a cooked taste which appears at about 70° C. This is due perhaps to the decomposition of certain of the proteins in the milk. The loss of certain gases also alters the taste. Heating milk openly drives away off-flavors.

Milk heated in the open air forms a pellicle which renews if it is removed. This scum forms when milk reaches about 60° C. It consists of:

	<i>Per Cent</i>
Casein and albuminoid . . . . .	50.86
Fatty matter . . . . .	45.42
Ash . . . . .	3.72

Milk heated in closed vessels does not form a pellicle, even when the temperature reaches the boiling point. It seems that this pellicle is due mainly to the drying of the upper layer of the liquid.

Heat causes a progressive decline in the hydrogen ion concentration of the milk as the temperature rises. Evidently, the heat modifies the balances of colloids in the milk.

It is claimed that heat influences the availability of calcium and phosphorus of the feeding mixture. Boiled milk for infant feeding has its advocates both here and abroad.

**RELATION OF PASTEURIZATION TO SCURVY AND RICKETS.** Milk contains but a moderate and variable amount of antiscorbutic property, vitamin C. The amount of this dietary factor depends upon the quantity contained in the feed of the cow. Stall-fed cows in winter furnish a milk almost devoid of antiscorbutic property. This vitamin is influenced by age, oxidation, and, to a certain extent, by heat. Experiments have shown that the temperature of pasteurization recommended decreases this property in milk about one-fifth to one-half. In any case, cow's milk cannot be depended upon to protect children against scurvy, and they should, therefore, receive orange juice or tomato juice, whether the milk is raw or pasteurized.

Milk at best has but moderate antirachitic property, vitamin D, which is not affected by heat. Rickets, therefore, cannot be laid at the door of pasteurization. It may readily be prevented by the use of cod-liver oil and the benefits of sunshine.

**CARE OF PASTEURIZED MILK.** Pasteurized milk must be handled at least as carefully as raw milk. It is just as apt to become infected if exposed. Bacteria grow even more rapidly in heated than in fresh raw milk. The bacteriostatic properties of milk are destroyed by heating above  $158^{\circ}\text{F}$  ( $70^{\circ}\text{C}$ ) but are little influenced at  $142\text{--}145^{\circ}\text{F}$  for 30 minutes (see page 878). There is a plentiful lack of understanding concerning the relative growth of bacteria in raw or heated milk. From a practical standpoint, this question can be disregarded, for the pathogenic germs that concern us particularly are just as harmful if taken in raw milk as in heated milk.

Pasteurized milk should be cooled and transferred to the bottler through a closed system, bottled and capped by machinery immediately following the process, kept cold and delivered promptly. The bottles should first be disinfected with steam or scalding water. All milk, whether raw or pasteurized, should be kept *clean, cold and covered*.

**OFFICIAL CONTROL.** Pasteurization is too important a public health measure to leave to individual caprice. The process should be under official supervision. The operator should be trained and licensed. The sanitary code should clearly define the requirements, and pasteurized milk should be labeled as such. Action for misbranding may be taken for milk labeled "pasteurized" but which has been processed by improper or incomplete methods. Milk should not be pasteurized twice.

Milk should be pasteurized at some central station where it may be done scientifically under official surveillance. In other words, it should be done for the householder just as in the case of central water purification plants. If water needs filtration or chlorination, experience teaches that it is inadvisable and expensive to depend on the householder to carry out the process. The same is true with pasteurization.

Pasteurizing machinery must be of a type approved by the state health authorities, well designed, properly run and kept clean and in good order. It should have automatic temperature control and automatic temperature recording devices, and the records should be kept for official inspection. From time to time the thermometer and thermoregulators should be standardized and the process controlled by physical and bacteriologic methods to insure its effectiveness.

**METHODS OF PASTEURIZATION.** There are six methods of pasteurizing milk: (1) the flash method, (2) the high temperature-short time method, (3) the holding method, (4) continuous flow, (5) the vat method and (6) in the final container.

*The Flash Method.* The flash method consists of heating milk momentarily to a temperature of about  $158^{\circ}\text{F}$  and chilling at once. This is done by allowing it to flow as a thin film on the outside of a steam coil, and then over cold metal. The temperature is uncertain and the holding time is left to chance. It does not give uniform results and is not entirely reliable, and hence does not meet with the approval of the sanitarian. The method, however, is rapid and cheap.

*High temperature-short time methods* of pasteurizing milk have been devised that are recognized by the U. S. Public Health Service and a number of states. Every article of the milk should be heated to not less than  $161^{\circ}\text{F}$  and held at this temperature or higher for not less than 15 seconds. Some of the milk may be heated by steam or by an electric current. A rapid method known as Electropure depends



upon an electric current heating a column of milk as it flows between two electrodes. The heating effect is uniform and rapid, the rate can be controlled and the milk can be held before cooling. Temperature control is precise, and a flow diversion valve functions automatically to return any unheated milk for heating to 161° F. Any mechanical failure results in stopping the flow of milk.

*The Holding Method.* The holding method consists of heating the milk to the desired temperature (142°-145° F) and holding it in a suitable tank at that temperature for a given time (30 minutes). In this way none of the milk escapes the disinfecting power of the heat, and the pathogenic bacteria in question are killed with certainty. The use of leak-protected inlet valves with an air relief, leak-protected and close coupled outlet valves, air space heaters, accurate and easily read indicating and recording thermometers, and automatic temperature controls have eliminated the questionable features of old pasteurizers of this type. This method has proved satisfactory in practice under commercial conditions. From the holding tank the milk should be run directly to the cooler and thence to the bottling machine through a closed system.

*Continuous Flow.* In this method the milk is first heated to 143° F or more and then permitted to flow through a series of tanks or coils of metal tubes. The rate of flow is adjusted so that the heated milk remains for 30 minutes in the apparatus. Experiments have shown that there may be mixing and irregularity in the time of flow unless the apparatus is well designed; the method is not extensively used.

Continuous flow pasteurizers also have been devised consisting of a series of four or more holding vats or pockets, in two or more of which milk is held at 143° F while one is being filled and another emptied. The inlet and outlet valves are operated either mechanically or manually to provide a continuous flow with 30 minutes holding. When dead ends are eliminated, and all valves protected against leakage and air binding, this equipment is satisfactory.

*Pasteurization in the Final Container.* In order to heat milk in bottles, they should be well sealed with an effective stopper. They may be heated by a shower of hot water or by steam. The simplest method, which is useful in an emergency, is to place the milk bottles in a water-bath brought to the proper temperature, held there a sufficient length of time and then chilled. Several types of machinery are in use for this method. One borrowed from the beer industry consists of a revolving drum in a metal cylinder, in which the filled bottles are subjected to a spray of hot water, and before completing the revolution are chilled. Another type of device is by endless conveyors, which carry the bottles through first a trough of hot water and then cold. Pasteurization in the final container is called the perfection of the art. It has the theoretical advantage that contamination after pasteurization is entirely eliminated. Practical disadvantages have been that temperature stratification occurs in heavy weight glass milk bottles and applied temperatures have not been uniform where solid bottle crates have been used and steam or hot water applied through perforations. Efficient equipment has been devised using light weight glass bottles, welded wire crated and a deluge of temperature-regulated, circulated hot water.

**HOME PASTEURIZERS.** Freeman's pasteurizer for heating milk in individual feeding bottles in the home is most serviceable. The modification of Nathan Straus is shown in Figure 22-3. It is used as follows:

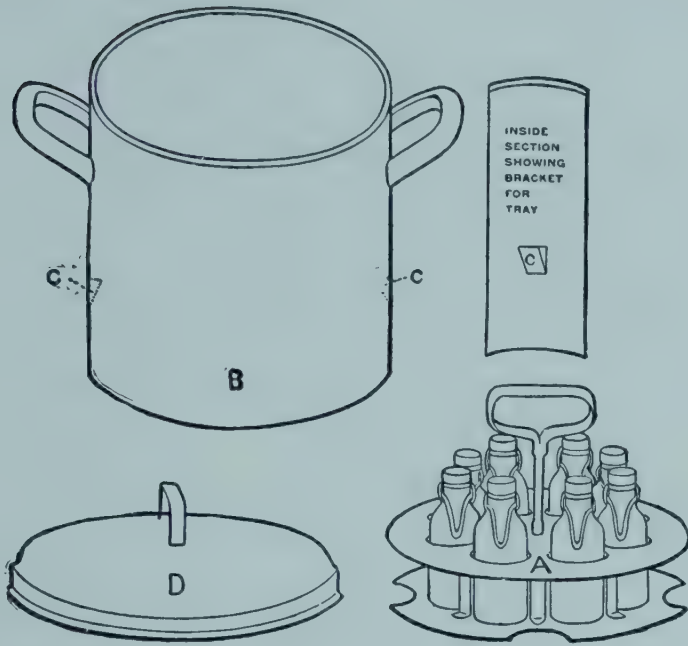


Fig. 22-3. Straus home pasteurizer.

After the bottles have been thoroughly cleaned they are placed in the tray (A) and filled with the milk or mixture used for one feeding. Then put on the corks or patented stoppers without fastening them tightly.

The pot (B) is now placed on the wooden surface of the table or floor and filled to the supports (C) with boiling water. Place the tray (A) with filled bottles into the pot (B) so that the bottom of the tray rests on the supports (C), and put cover (D) on quickly.

After the bottles have been warmed up by the steam for five minutes, remove the cover quickly, turn the tray so that it drops into the water, replace the cover immediately. This manipulation is to be made as rapidly as possible to avoid loss of heat. Thus it remains for 25 minutes.

Now take the tray out of the water and fasten the corks or stoppers airtight. Cool the bottles with cold water and ice as quickly as possible, and keep them at this low temperature until used.

Use the milk from the bottles and by no means pour it into another vessel.

The milk should not be used for children later than 24 hours after pasteurization.

Emphasis is laid on the fact that only fresh, clean milk, which has been kept cold, should be used.

**The Essential Requirements for a Safe and Satisfactory Milk Supply.** 1. Cows should be healthy and free especially from communicable infections, or any febrile disease, or inflammatory condition of the udder.

2. All persons who in any way come in contact with the milk or milk apparatus should be free from communicable diseases and not be carriers. A minimum of human contact should be insisted upon.

3. The milking should be done in clean surroundings, the udders washed; the



hands of the milker should be clean and dry; the fore milk should be discarded and good dairy technic observed.

4. The milk should be received into clean, sterilized pails, seamless and with a small mouth so as to keep out dust and dirt which fall from the udder and belly of the cow. Strainers should be cleaned and boiled morning and evening. Cans and pails should be cleaned with washing soda or alkaline powder (not soap), rinsed in clean water, and then steamed or boiled or chlorine sterilized.

5. The milk should be chilled to 50° F or under at once, and kept protected from flies, dust, odors, and contamination, in a clean milk house until collected.

6. The milk in transit to the city should likewise be kept protected and cold, not higher than 50° F, and guarded against tampering en route. The lower the temperature the easier it will be to keep the bacterial count down. Milk should not be frozen.

7. All apparatus at the city dairy, such as tanks, clarifiers, separators, pasteurizers, and bottling machines, should be kept scrupulously clean and sterilized daily with steam or chlorine.

8. Pasteurization should be followed by rapid chilling and the milk kept below 50° F until delivered to the consumer. Milk and cream used for making milk products should also be pasteurized.

9. The pasteurized milk should be bottled and capped by machinery in sterilized bottles, well sealed; and delivered promptly to the consumer.

10. All bottles and cans, after use in city delivery, should be washed and sterilized before being returned to the producer in order to prevent the conveyance of infection to the dairy or country farm.

11. The milk must be graded, even if there is only one grade. In this way the producer is paid for care and cleanliness and the consumer has a ready means of knowing the sanitary character and nutritive value of the milk he purchases. Grading and labeling help the official control.

12. Laboratory aid is essential, including frequent bacterial and chemical analyses. Sanitary surveys and inspections from the producing farm to the consumer are a fundamental part of the program.

13. A sanitary code based upon good milk laws, which include milk products, should be enforced.

14. A system of licensure, inspection and education to insure the above requirements should be followed.

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# 23

## MEAT, FISH, EGGS, AND PLANTS

### MEAT

Meat (Edelman, 1933) is an important item of diet throughout the world. Man selects his meat from a wide range of animal life. Herbivorous mammals and certain omnivorous animals are the chief sources, while the flesh of carnivora is distasteful to civilized peoples. Next to mammals, birds and then fish supply our food.

In some countries the flesh of horses, dogs and cats is eaten. In Germany horses and dogs are slaughtered and regularly inspected for human food. The meat of these animals is also used in other countries that have long been flesh hungry. There is no sanitary objection to the use of such meat if derived from healthy animals. Horse meat, when eaten for beef, makes no unpleasant impression. In Paris, Vienna and other cities large numbers of horses, mules and donkeys are slaughtered for food.

**Structure and Composition.** Meat is composed of muscular fibers and associated structures, such as connective tissue, blood vessels, nerves, lymphatics and more or less adipose tissue. The muscle (flesh) of an animal consists of highly specialized contractile tissue. It is also a storage organ in which glycogen and fats are held for reserve. It contains little of the cell structures of such glands as are found in the liver, kidney and pancreas. Chemically, muscle consists principally of protein, salts and water and the reserve foodstuffs. Muscle tissue contains less nucleic acid by weight than the glandular organs. The inorganic content of muscle tissue resembles that of the seed rather than the leaf of the plant, both in amount and in relative proportions among the elements. Muscle contains about 25 per cent solid matter, of which four-fifths is protein, one-fifth extractives and inorganic salts. About 75 per cent of the protein is made up of a coagulable albumin (myosin). The non-nitrogenous extractives are glycogen, hexosephosphate, lactic acid, inositol and fat; and the nitrogenous extractives are creatine, purine bases (xanthine, hypoxanthine), uric acid, adenylic acid, inosinic acid, carnosine (ignotine) and carnitine (novaine). Potassium phosphate is the predominating salt of muscle. Iron exists chiefly as hemoglobin, belonging in part to the muscle cells and in part to retained blood.

The toughness of meat is due to the thickness of the walls of the muscle tubes and excess of connective tissue which binds them together; hence, the flesh of young domesticated animals is usually more tender than that of old or wild animals. Freshly dressed meat is alkaline in reaction. Soon after death rigor mortis sets in and the reaction becomes acid due to the development of lactic acid, called in meat sarcolactic acid. During this process the connective tissue and muscular fibers become softened, thus rendering the muscular structures more tender.

The flavor of meat varies more or less with the age of the animal, its food, breed

and condition at time of slaughter, and the handling of the meat after slaughter. The flesh of sexually mature male animals is usually stronger in odor than the meat of females or young or castrated males. This is particularly true of goats and swine.

**Nutritive Value.** The nutritive value of meat depends mainly upon the presence of proteins and fats. Nitrogenous extractive matters, such as creatine, xanthine and similar substances, sometimes called meat bases, which are formed by cleavage of the proteins, are of little value as foods. These nitrogenous extractives are present in about the same amount in both red and white meats; in fact, there is no essential difference between red meat and white meat except for the presence of pigment.

Animal tissues fall into two groups: (1) glandular organs as the liver and the kidneys; (2) the highly specialized muscle tissue. The proteins of muscle and the glandular organs are complete as sources of amino acids.

The dietary properties of meat are comparable with the seed rather than the leaf of plants; in fact, muscle tissue differs markedly from the seed in only one respect when considered as a foodstuff, namely, in the quality of its proteins. The proteins of meat are complete, those of seeds incomplete. Both meats and seeds are poor in mineral salts, which are necessary in the diet. Both muscle and seeds are relatively poor in vitamin A as compared with such foods as milk, egg yolk and the leaves of plants. Meat is an admirable source of protein of good quality. It is appetizing, satisfying and stimulating. The condimental value of meat is high. Meat is an essential part of an optimum diet. On the other hand, growth and nutrition cannot be maintained on meat alone because it is so deficient in many of the necessary dietary factors. Carnivorous animals in the wilds make up this deficiency by drinking the blood, gnawing the bones and eating the liver of their quarry.

There is little difference in the composition and nutritive value between the meats of mammals, birds and fish. Meats from different sources and even from the same source differ chiefly in the amount and character of the fat they carry. The flesh of fish ordinarily is not classed as meat, but it has the same muscular structure and similar chemical composition and nutritive value as mammals and birds (see page 904).

**Beef Extracts.** Beef extracts are nothing more or less than a soup or soup stock specially prepared. They first became generally known through the researches of Liebig and are now an important article in commerce. The ordinary beef extract found on the market contains from 15 to 20 per cent of moisture, from 17 to 23 per cent ash, and from 50 to 60 per cent of meat bases, and but a trace of soluble albumin, albumoses and peptone. Meat extracts contain little nutritive matter, although this being soluble is readily digested. These extracts may be useful as stimulants or as condiments, or as a means of speedily introducing a small amount of nutriment in the case of disease.

A distinction should be made between beef extract and beef juice. *Beef juice* is obtained by strong pressure of fresh lean meat which is concentrated *in vacuo*, or it may be freshly prepared in the household. Beef juice contains much more albuminous nutrient material than beef extract, provided the protein is not coagulated by heat and separated out.

**Differentiation of Meats.** The meat of any species may be determined readily by means of the specific precipitins; also by physical, microscopical, chemical or biological tests. Meats from different animals usually may be distinguished by their



odor, taste or appearance. Microscopically the fibers resemble one another so closely that this test is not reliable. There is some variation chemically in meat from different species, from different animals of the same species, and even from different muscles in the same animal. Meats from animals of different species differ principally in glycogen and fat content. The glycogen content may be changed as a result of bacterial action, hence the test for fat is the more satisfactory. The fats of different animals have different physical and chemical characteristics; they crystallize in different forms and have different melting points, as also the fatty acids derived from them. A careful examination of the fat will determine approximately the character of the flesh from which it has been derived.

**Raw Versus Cooked Meat.** Meat should not be eaten raw. Individual cysticerci (tapeworm larvae) are easily overlooked, and one is enough to bring forth a tapeworm. It is also not practicable to examine the flesh of all hogs for trichinae, and even though this were done with care the method does not afford complete protection. It is again emphasized that some of the more serious bacterial infections do not alter the color, taste or appearance of the meat in any way. Raw meat does not have a higher nutritive value than cooked meat. Thorough cooking is our ultimate safeguard against infection.

#### MEAT INSPECTION

**Importance of Meat Inspection.** The flesh of food animals may be objectionable or harmful through disease or parasitic infection; the meat of a healthy animal may develop noxious qualities after slaughter through deteriorative changes, or infection through unsanitary handling. Not every disease makes the flesh of an animal unsafe or unfit for food. Thus, in order that the established principles of pathology may be accurately applied so far as practicable, a skilled inspection and supervision of food animals and their products becomes necessary to protect against possible dangers. This obligation is assumed by the state or national government.

An efficient meat inspection service, in addition to being a protection to man, is an effective agency in locating and eradicating dangerous diseases from food herds. Competent inspection at places of slaughter will discover the first appearance of rinderpest, foot and mouth disease, Texas fever or other epizootic; or herd diseases, such as tuberculosis, actinomycosis and hog cholera. Effective measures may be instituted at once and great economic loss averted.

The practices of meat inspection vary in different countries. Thus, in countries which have long had a scarcity of meat, much is passed for food that would be condemned under the federal system in the United States. Where lack of abundance prevails a sharp watch must be maintained to prevent the people from eating meat known to be injurious. In America, where meat has been plentiful, the attitude is different and even meat known to contain a harmless parasite may be repugnant to some. Scarcity and higher prices will overcome this supersensitiveness. The need of conservation during and since the World Wars has placed our national meat inspection service on a more practical basis, without sacrificing good standards.

The prevention of infections and poisoning from meat and meat food products depends first of all upon the health of the animal, next upon the mode of death, and finally upon the methods of butchering, preserving and handling the flesh. Careful attention to every detail is necessary throughout. Cleanliness approaching surgical

methods during the preparation, transportation and handling of the meat is called for.

A corps of thoroughly trained meat inspectors is one of the most important links in the chain of an efficient meat inspection system. A meat inspector should be a qualified veterinarian having special training and experience. He should know the anatomy of the various food animals and be acquainted particularly with the infectious diseases which prevail in the district where he is situated.

**The Public Abattoir.** The first essential of a good meat inspection service is to concentrate all slaughtering in central abattoirs. This simplifies inspection and sanitary control and protects the consumer. In Germany, England, Australia and New Zealand municipal public abattoirs have been established. Each person who wishes to slaughter must obtain a permit and pay rent. The erection and maintenance of well-controlled, modern public slaughterhouses is one of the needs of our country, especially in the smaller towns.

The building must be especially well constructed and kept clean. Only good and wholesome water and ice should be used in the preparation of the carcasses, and the wagons and cars and all surfaces with which the meat comes in contact should be kept clean and in good sanitary condition. Slaughtering and butchering involve more or less blood and refuse matter, hence the necessity of frequent and repeated cleaning. The inedible products tanking department, fertilizer department, hide room, casing room, toilet rooms and dressing rooms should be entirely separate. Sources of odor that may contaminate the meat or be otherwise objectionable must be eliminated, and every effort made to keep out flies and other vermin, especially rats and mice. Dogs should not be allowed within slaughterhouses on account of the danger of spreading the *Echinococcus* and other parasites. The uncooked refuse of slaughterhouses should not be fed to hogs.

The employees must be free from infections that may contaminate the meat, be cleanly and wear outer clothes that may be laundered readily. The hands should be washed before beginning work and after each visit to the toilet. Butchers should thoroughly cleanse their hands after handling a diseased carcass. Implements used on such carcasses should be sterilized in boiling water.

The spoiled portions of meat that fall upon the floor or otherwise become soiled should be condemned. All carcasses, parts of carcasses, and meat products that have been condemned for food purposes should be destroyed.

#### THE UNITED STATES FEDERAL MEAT INSPECTION SERVICE

The U. S. Federal meat inspection law, approved March 18, 1907, and as amended at various times since, provides for the inspection of cattle, sheep, goats, swine, and, in a restricted way, of horses, the meat or products of which animals are to enter interstate or foreign shipment. The law is administered by the Bureau of Animal Industry, U. S. Department of Agriculture.

The purpose of a meat inspection service is to eliminate diseased or otherwise unsound meat; to require cleanly and sanitary precautions in the preparation and processing of foods composed wholly or in part of meat; to prevent the use of harmful dyes, preservatives, chemicals or other deleterious substances, and false and misleading labels and statements.

In magnitude, the U. S. Federal Meat Inspection Service stands alone among the meat inspection systems of the world. The government is expending annually



about \$14,325,000 toward supplying wholesome, clean and unadulterated meat and meat food products. During the fiscal year 1955, federal meat inspection was maintained in 1,149 slaughtering, packing, rendering and meat-preparing plants located in 446 different towns and cities, and included most plants of considerable size or importance in the United States. The year's slaughter of these inspected establishments was in round numbers 18,643,780 cattle, 7,563,234 calves, 14,432,021 sheep, 86,205 goats, 56,951,433 swine and 236,424 horses, a total of over 97,913,097 animals. The federal system may be regarded as consisting of five continuous and coördinating inspections, namely, (1) sanitation, (2) the ante-mortem or live-animal inspection, (3) the postmortem or slaughter inspection, (4) the products inspection or supervision of processing and manufacturing meat food products, and (5) the laboratory inspection.

**Sanitary Inspection.** The federal regulations require certain definite and important requirements to be met satisfactorily before sanctioning an establishment. There must be adequate light and ventilation, pure water supply, efficient floor drainage and modern plumbing and sewerage. Smooth and impervious material must be used in the construction of building and equipment. Separate modern and sanitary toilet and dressing rooms, lavatories for cleansing hands, and equipment for disinfecting utensils must be provided. All rooms in which meat and products are stored or handled must be separate from those in which inedible products are stored, handled or treated. Cleanliness must be observed throughout.

**Ante-Mortem Inspection.** Animals about to be slaughtered, if found affected, or suspected, are separated from the rest. Those which show symptoms of particularly virulent diseases and those in a moribund condition are condemned outright, and the remainder are slaughtered separately and given expert veterinary postmortem inspection.

**Postmortem Inspection.** The postmortem inspection is an autopsy performed during the process of dressing the carcass. It consists of an examination of the principal groups of lymphatic glands, of the head, viscera, tongue, lungs, heart, liver, spleen and kidneys, the peritoneal and thoracic membranes, exposed bones, joints and surfaces of the carcass. Abnormal or diseased carcasses are subjected to expert veterinary inspection. Carcasses or parts were condemned by the Federal Meat Inspection Service during the year 1949 for more than 40 diseases and conditions, among which were anthrax, tuberculosis, hog cholera, pyemia and septicemia, actinomycosis, caseous lymphadenitis, cysticercosis, emaciation, carcinoma, leukemia, icterus, immaturity, pregnancy, sexual odor, parasitic infestations, abscesses, bruises, dropsical conditions and asphyxia. A few of the more significant of these diseases are discussed below. In 1955, nearly 98,000,000 animals passed post-mortem inspection and 281,664 were condemned as a result of such inspection.

**Products Inspection.** Meat products are inspected and passed in the same manner as meats. The inspection covers all such processes and operations as rendering, curing, smoking, cooking, mixing, canning, manufacturing and labeling. In the year 1955, this amounted to 16,373,853,029 inspection pounds. All meats and products are subject to inspection and reinspection at any time to determine whether they have remained sound. The purpose of this inspection is to see that sanitary conditions are maintained; that harmful substances are not used; and that the meat products shipped are sound, wholesome and correctly labeled.

Under federal requirements all condemned carcasses and parts are effectually destroyed for food purposes under direct supervision of inspectors. Carcasses and organs passed for food are marked "U. S. Inspected and Passed."

The regulations of the United States Department of Agriculture permit the addition to meat or meat food products of the following substances: common salt, sugar, wood smoke, vinegar, pure spices, saltpeter, nitrate of soda and nitrite of soda. Benzoate of soda may be added to meat and products only when declared on the label with percentage used. Only such coloring matters as may be designated by the Secretary of Agriculture may be used under prescribed limitations and declarations. The adulterants most commonly used in meats are boracic acid, borax, sulphite of soda, and benzoic acid.

**Laboratory Inspection.** The government maintains well-equipped district chemical laboratories at convenient points throughout the country. In these laboratories analyses and examinations are made of meats and meat food products, as well as of the water supplies, curing materials, spices, cereals, denaturing oils and other substances.

**Need of State and Municipal Inspection.** About one third of all animals slaughtered for food in the United States do not have federal inspection. A few of the states and a number of municipalities maintain meat inspection services varying considerably in enforcement, but in many places there is practically no control over meat that does not cross the state border.

#### DISEASES FOR WHICH ANIMALS ARE CONDEMNED

**Tuberculosis.** A nation-wide campaign against tuberculosis in cattle and swine has resulted in decreased prevalence of the disease and a marked reduction in the number of carcasses of these animals condemned on this account. During the fiscal year 1955, 580 cattle or 0.003 per cent, 7,311 swine or 0.11 per cent of the total killed and inspected were condemned on account of tuberculosis. This is a marked reduction over the figures for the year 1924, when 56,760 cattle or 0.618 per cent, and 100,110 swine or 0.184 per cent were condemned; and 7,184 cattle and 125,000 swine with limited tuberculosis were passed for cooking.

The line of demarcation between localized and generalized tuberculosis from the standpoint of meat inspection is frequently difficult to determine. If the lesions are not numerous, if there is no evidence of distribution of tubercle bacilli throughout the blood, and if the animals are well nourished and in good condition, there is no reason to suspect that the flesh is unwholesome, and it is permitted to be used after the removal of the affected parts. Evidence of generalization of the process is indicated by fever before slaughter, anemia, cachexia, emaciation; generalized or extensive lesions in one or both body cavities; or lesions in the muscles, intermuscular tissues, bones or joints; or multiple, acute or actively progressive lesions. Fortunately, tuberculosis of muscle is exceedingly rare and thorough cooking is sufficient to kill the tubercle bacilli. The relation of bovine tuberculosis has been discussed on page 145.

Tuberculosis of cattle shows itself in four primary lesions: (1) the retropharyngeal lymph nodes, (2) the lungs and associated lymph nodes, (3) the mesenteric lymph nodes and (4) the liver. From the retropharyngeal nodes the process extends to the cervical lymph nodes and also to the anterior mediastinal lymph nodes. When



this group of glands alone is infected the disease may be considered as localized. From the mesenteric lymph nodes the infection frequently reaches the peritoneum, and from the bronchial lymph nodes the pleura. The newly formed growth in the peritoneal or pleural cavities may be enormous in amount. It is often suspended from the omentum in great grape-like masses (Perlsucht), or the intestines may be plastered with tubercles. In these cases the animal otherwise may be in good condition; that is, the disease is still outside the vital organs and the tubercle bacilli have not invaded the blood stream. In Germany it is permitted to cut off such growth and allow the meat to go into consumption. In the United States, the meat of such animals is condemned. Carcasses which cannot be passed, but which are not sufficiently severely infected to be condemned, may be rendered into lard or tallow or otherwise cooked, provided the parts containing tuberculous lesions can be removed.

In Germany tuberculous and trichinous meat is cooked and sold as second quality meat in accordance with the third class or "*freihank*" meat system. There is no known sanitary objection to this practice, provided the cooking is complete and the label represents the true nature of the product.

**Anthrax.** All carcasses showing lesions of anthrax, regardless of the extent of the disease, are condemned and immediately destroyed. This includes the hide, hoofs, horns, viscera, fat, blood, and all portions of the animal. The killing bed upon which the animal was slaughtered must then be disinfected and all knives, saws and other instruments that have come in contact with the infection must be boiled or otherwise disinfected.

**Hog Cholera.** Carcasses showing well-marked and progressive lesions of this disease in any organ or tissue are condemned. If the lesions are slight and limited they may be passed for cooking. Man is not susceptible to hog cholera.

**Actinomycosis.** If the animal is in a well-nourished condition and the disease has not extended from a primary area of infection the carcass may be passed for food after condemnation of the infected organs or parts; but if the disease is generalized the entire carcass is considered unfit for human use and should be condemned.

**Tapeworm Cysts.** Carcasses of animals affected with tapeworm cysts are condemned if the infestation is excessive. Carcasses of cattle showing a slight infestation may be passed for food after removal and condemnation of the cysts, provided complete destruction of any hidden cysts is insured. Cold storage or pickling for not less than 21 days, or storage for six days at a temperature not exceeding 15° F will destroy the cysts. Such carcasses may also be passed for cooking.

Carcasses or parts of carcasses found infected with hydatid cysts (*Echinococcus*) may be passed after condemnation of the infected part or organ.

**Septic and Pyemic Conditions.** Carcasses of animals so infected that consumption of the meat or meat food products may give rise to meat poisoning should be condemned. For the information of the inspector the following conditions are specified: (1) acute inflammation of the lungs, pleura, peritoneum, pericardium or meninges; (2) septicemia or pyemia, whether puerperal or traumatic or without any evident cause; (3) severe hemorrhagic or gangrenous enteritis or gastritis; (4) acute diffuse metritis or mammitis; (5) polyarthritis; (6) omphalophlebitis; (7) traumatic pericarditis; (8) any other inflammation, abscess, or suppurating sore, if associated with acute nephritis, fatty and degenerated liver, swollen soft spleen.

marked pulmonary hyperemia, general swelling of the lymphatic glands, and diffuse redness of the skin, either singly or in combination.

Immediately after slaughter, the premises and implements used must be thoroughly disinfected. Any carcass which has been exposed to contamination should also be condemned.

**Poisons in Meat.** Meat may occasionally be injurious to health from a variety of miscellaneous causes. Thus, an animal that has died of arsenic or other poisonous substance may contain sufficient of the poison in the tissues to affect the person who eats part of the flesh.

The belief that sickness in man can follow the consumption of the flesh or milk of animals which have previously fed upon poisonous plants is not unfounded. Chesnut states that poisons from various plants have been isolated from honey, which may also contain as much as three grains per liter of formic acid.

**Bob Veal.** Bob veal is the flesh of calves less than two or three weeks old. Bob veal is not objectionable from a health standpoint, and the prejudice against it is illogical. There is no similar prejudice against eating suckling pig or the immature of other animals. The meat is flabby, edematous, soft. The connective tissue is gelatinous and is present in greater quantity than in mature animals. The fat is reddish-gray and soapy, the meat less nutritious in value, as it contains a large proportion of water. The digestibility of the protein of bob veal is the same as market veal, namely, 93 per cent. On account of its moist and soft condition, bob veal has a greater tendency to spoil than the flesh of mature animals. Young calves are highly susceptible to a number of infections, particularly diarrheal diseases and infections which enter through the navel, but trouble has seldom been traced to bob veal. Bollinger and also Ostertag have reported a few cases of illness due to eating the meat of diseased animals. Infections may be guarded against by care, inspection, and thorough cooking.

## ANIMAL PARASITES TRANSMITTED TO MAN

GILBERT F. OTTO, Sc.D.

**Trichinosis, Trichiniasis, or Trichinelliasis.** *Trichinella spiralis*, commonly known as trichina, is a nematode (roundworm) which passes its entire life cycle in a single mammal. It differs from most other metazoan parasites of man in at least two significant aspects: (1) it is an obligatory parasite throughout its entire life history and has no free-living stage; it survives for relatively short periods after the death of the host only when encapsulated within the skeletal musculature; and (2) it is lacking in host specificity; it will develop similarly in any mammal so far as is known; certainly there are no records of failure in adequate attempts to infect any species of mammal and over 25 species have been found naturally or experimentally infected. In addition, with proper preparation, birds and amphibians have been experimentally infected but none has ever been found naturally infected.

Trichinosis is a common and important infection but the means of prevention are, and have been for many years, readily available. Fortunately the mortality rate in this country is very low, ranging from 0 to 5 per cent in localized outbreaks, and confined to those who have a very heavy initial infection. When the



disease was first recognized in Germany, shortly after the middle of the past century, mortality rates as high as 30 per cent were reported.

**LIFE CYCLE OF *Trichinella spiralis*.** Infection is acquired by ingesting the raw or inadequately cooked skeletal musculature of infected mammals. The larvae coiled within a fibrous capsule within such muscle, escape within a few hours after ingestion, become attached to the mucosa of the upper part of the small intestine, mature and mate within two or three days. The male worms are thereafter quickly discharged in the feces while the females burrow deeper into the mucosa. Within a week they begin discharging larvae into the lymphatic spaces and continue the process until a few hundred to over a thousand are produced in the succeeding two to six weeks. These larvae, which are about 100 $\mu$  long and smaller in diameter than a red cell, upon reaching the heart are discharged through the systemic circulation to all parts of the body. Only those which reach the striated muscles are capable of further development; this development is completed within a month. By this time the larvae are encapsulated by host fibrous tissue, and are infective when eaten. Within two months the inflammation in the muscles has been resolved, except in very heavy infections, and only the fibrous capsules containing the larvae remain. Ultimately the capsule becomes calcified but that process in rats does not begin in less than six to eight months while in dogs and cats, and in man it may not begin for years. The calcification does not involve the larvae nor does it produce any discernible injury to them for some time; living and infective larvae may be recovered from capsules which have become completely calcified naturally or in which calcification has been induced by overdoses of parathormone or irradiated ergosterol and calcium salts (von Brand and others, 1938).

Larvae may leave the blood stream apparently in any organ or tissue of the body but are unable to complete their development in sites other than striated muscles. It appears from experimental work on mice that even transient penetration of tissues other than striated muscles is rare, about one larvae in 10,000 (Mauss and Otto, 1942) and that logically enough even these few are more commonly seen in the myocardium than in nonmuscular tissues.

**PREVALENCE AND GEOGRAPHICAL DISTRIBUTION.** Human infection is confined to those who eat the uncooked or inadequately cooked flesh of infected mammals. Hence it occurs as a disease entity only in those areas where such food habits are common. Thus the disease is all but unknown in the tropics and in the Orient. While fish is eaten raw as a delicacy in localized areas of the Orient, pork and the flesh of any other mammals are habitually cooked more thoroughly than is done by most Caucasian races. The writer distinctly recalls the visit of a distinguished Japanese parasitologist with decades of experience in Japan, Formosa, and the mainland who had never seen trichina. Except for a few outbreaks in South America (e.g., Chile) little evidence of the disease has been reported from the Southern Hemisphere; Australia, for instance, is notably free of the infection.

The disease is, therefore, of widespread public health concern at the present time only in the Northern Hemisphere. The most severe epidemics of this disease known were those which occurred in Germany 75 to 100 years ago, in the intervening century the disease has been brought under control in that country so that today it occurs only sporadically. Outbreaks of varying severity are reported from

austria and the Italian Tyrol, but elsewhere in Italy, Spain, France, Portugal, and the British Isles it is uncommon. Relatively little is known concerning its prevalence in Eastern Europe, but recurrent reports suggest that it is comparatively common in Czechoslovakia, Poland, and Russia. The infection, however, appears to be most common in the temperate zone in the United States. Numerous post-mortem surveys in the past two decades have indicated that about 15 to 20 per cent of the adult population harbor the infection. Most of such surveys have been made by the examination of a single small sample of the diaphragm, but Evans (1938) has presented evidence that the prevalence may really be much higher. Direct microscopical examination of two different samples of the diaphragm revealed, respectively, eight and nine positive in 100 consecutive autopsies. The complete digestion of the gastric and tendinous portions of the same diaphragms revealed, respectively, 16 and 17 positive. The increasing figures were not simple summations, however, and the total number of diaphragms positive was 20. Furthermore, when up to 75 gm. of sternomastoid and up to 100 gm. of intercostal muscles were digested, 16 new infections were revealed, bringing the total to 36 per cent infected. Such figures demonstrate that a very large portion of our population is infected, but, in addition, the more comforting fact, that most of the infections are apparently very light. Only 4,543 human cases of clinical trichinosis were reported to the United States Public Health Service between 1842 and 1936 (Sawitz, 1938). Since reporting of this disease is incomplete, we can safely assume that more actually occurred, and there may even have been more than the 5,000 to 6,000 which Schwartz (1938) estimated. It seems extremely unlikely, however, that there are "several hundred thousands who have had clinical trichinosis never diagnosed as such, and possibly several thousand deaths annually from this cause" as Hall and Collins (1937) estimate. Evidence has been presented (Hall and Collins, 1937) which suggests that the infection is much less in the deep south (3.5 to 6 per cent in New Orleans) and most common on the North Atlantic Coast (e.g., Queen, 27 per cent in Boston) and California (e.g., McNaught and Anderson, 1944, 4 per cent in San Francisco). These same authors, furthermore, call attention to the fact that the reported morbidity and mortality from this infection follow the same geographical distribution.

In Mexico the infection has been found recently to be much more common than hitherto expected, but it is still not comparable to the infection rate in the United States.

Canada is usually considered to be relatively free of the infection, but Cameron (1938) suggests that it may be much more common than realized, and, recently, has been reported as common in Vancouver, British Columbia.

Of considerable interest are the recurrent reports of trichinosis in the Arctic and nearctic regions, in Alaska, Northern Canada, Greenland, Iceland, the Northern parts of Scandinavia, Finland, Russia and Siberia. Clinical outbreaks have been reported from these areas (e.g., 33 deaths among 300 cases in Northern Greenland), and in 1949, 7 per cent of the Eskimos in the Bethel Area (near Anchorage), Alaska, gave positive reactions to the intradermal use of trichina antigen.

**SOURCES OF INFECTION.** In the temperate zone the principal source of human infection has been, and still is, raw or insufficiently cooked pork. It was raw pork which was the cause of most of the fatal infections in Germany a century ago,



and it is raw or insufficiently cooked pork which accounts for most of the present-day infection, i.e., roasts, chops, *fresh* ham, etc., but the commonest source appears to be *fresh* pork sausage. Furthermore, severe clinical outbreaks involving whole families or other, even larger, groups of people are almost invariably traced to a single hog which is eaten without mixture with other pork; or from sausage made from, at most, two or three hogs, one of which is infected. Since usually only a small percentage of hogs are infected, and most of them lightly, trichina are diluted in sausage made at large abattoirs. Since most human infections are subclinical or mildly clinical, it is probable that the latter sausage is one source of these infections; sporadic clinical cases have also been traced to such meat. Other sources are probably inadequately cooked roasts, chops, sausages, etc. in which many, but not all, trichina are killed. While it is not impossible that an occasional light infection may be acquired from processed meat such as smoked ham, no such meat has ever been directly incriminated as a source of infection, and the examination of over 16,000 one-half pound samples of various processed pork products has failed to reveal that any of them contain infective larvae (Harrington and others, 1950; Zimmerman and others, 1955).

Since Leidy's discovery in 1846 of trichina in pork, identical to that in man, there has been much study, and even more speculation, on the source of the porcine infection. The finding of 1.4 per cent infection in the routine microscopic inspection of 8,000,000 hogs killed under federal inspection from 1898 to 1906 does little more than indicate the scope of the problem. Many continued to subscribe to the theory Leuckart had earlier advanced in Germany that hogs became infected from eating rats. To this was added the refinement that such infections took place in abattoirs where rats are heavily infected. We may safely discard these theories; the abattoir as a source of infection is of no concern since hogs are not held there more than a few days; and a minimum of three to four weeks are required for the maturation of the infection. It may be that rats are the source of some of the comparatively few infections reported in grain-fed hogs, but this has yet to be demonstrated. It is more probable that the rat is another victim of the disease rather than a source of infection for hogs.

The real source of porcine infection in the United States was demonstrated in 1888 by Mark in Boston. In the preceding five years the examination of over 3,000 hogs from garbage feeding piggeries in the vicinity of Boston had revealed 9 to 16 per cent infection in the several lots with an average of 13 per cent, whereas the examination of 500 "Chicago hogs," largely grain fed, had revealed only 2 per cent infection. Even more striking was his report, 1894, from the experience of North Hampton Lunatic Asylum. Up to 1887, hogs there had been fed upon kitchen garbage and slaughterhouse refuse with the result that 26 and 63 per cent of the hogs killed in 1885 and 1886, respectively, were infected. After January 1, 1887, the practice of feeding slaughterhouse refuse was terminated and only cooked kitchen garbage was fed, with the result that the infection rate dropped rapidly to 0 in 1893 to 1894, and it was ascertained that a number of the 25 positive hogs killed from 1887 to 1893, including the one positive in 1893, were born during the garbage feeding practices of 1885 to 1886.

More recently, Schwartz (1939) reports 4.4 per cent infection in a miscellaneous group of over 6,000 garbage-fed hogs and 0.9 per cent in similar group of

grain-fed hogs, and 0.6 per cent in over a thousand hogs fed on cooked garbage. Kerr, 1940, reported less than 0.5 per cent infection in California grain-fed hogs, and over 6 per cent in raw-garbage-fed, with the latter running over 12 per cent in some groups of hogs from the northern part of the state; interestingly enough, no infection was found in hogs fed on cooked garbage. Similar reports have come from Vancouver, B. C. It seems evident then, that the bulk of the porcine infection is associated with the practice of feeding raw garbage, but the source of the occasional infection in grain-fed hogs is not at once evident. It has been suggested that rats may be the source of the infection of such hogs, but Mark pointed out the difficulty of tracing the full history of any given hog. Kerr did succeed in tracing the history of some of the grain-fed hogs. He found that they had only been fattened on grain after having been raised on raw garbage and that such hogs had three times the infection rate of the remaining group of grain-fed animals. Furthermore, he was unable to find any trichina in rats or other rodents trapped around the grain feeding pens, but those trapped in raw-garbage feeding pens harbored about the same infection rate as the hogs feeding there. This would seem to support the earlier statement that the rat is another victim of the infection and not an indirect disseminator to man.

Although garbage-fed hogs are the primary source of infection in the United States, there have been small outbreaks traced to inadequately cooked meat of other animals, notably the bear. Bears, near common picnic or camping grounds, have had easy access to garbage.

Further, while pork was apparently the primary source of infection in Germany up to a half century ago, there is now relatively little infection found in German pork. Fischer, 1934, reported one to eight infections per year since 1924 out of an average of 30,000 hogs killed and subjected to routine microscopical examination in Linz each year; Mayer in 1939 reported the *first* positive in the 100,000 hogs killed and inspected in Heidelberg in the preceding five years. Todd, 1948, reported that of the total of 79,000,000 hogs butchered and inspected in all of Germany from 1934 to 1937 less than 0.0005 per cent (actually 44 per 10,000,000) were found to be infected. Similarly, Hjortland, 1935, reported routine microscopical inspection of pork in Denmark has failed to reveal a single trichina infection in the last five years and only 45 in over six million hogs examined in the last 25 years. Although this is lower than the swine infection rates in the United States during the same period, it seems evident that the infection was never as frequent in swine in Germany as in American garbage-fed hogs. Although rates of 1 to 2 per cent have been reported in small groups of hogs in Germany, the rate for the 2.5 million hogs in the first year of inspection in Prussia (1878) was less than 0.1 per cent, and no figures materially higher have been found for any period since. Since raw pork sausage is considered a delicacy and commonly eaten when available in a number of places in Germany, there was ample opportunity for infection through the eating of pork despite the low infection rate in hogs. Evidence is accumulating that at least the severe outbreaks in Germany in recent years have resulted from meats other than domestically raised pork; wild boar and other game animals have been incriminated a number of times.

In the Arctic and Nearctic regions man is infected almost exclusively from the meat of wild animals. Of these the polar bear appears to be the commonest source



of human infection; this bear is both a scavenger and a predator on small animal and has ample opportunity for infection. A number of outbreaks have been traced directly to these animals, and the microscopical examinations in limited survey have revealed as high as two out of three infected. A wide variety of other Arctic mammals have been found infected and a number, such as the walrus, seal, and even the white whales, have either been directly incriminated or are under serious suspicion as the source of infection and disease in man.

**CHARACTERISTICS OF THE DISEASE.** Not everyone who becomes infected suffers the disease. The occurrence and severity of the disease are apparently almost entirely dependent upon the number of infective larvae ingested in the case of an initial infection. Since, in the United States, most infections appear to be acquired from inadequately cooked, rather than raw pork, and in the case of sausage, the trichinous pork is usually heavily diluted with nontrichinous pork, the resulting infections are light. It is probable that most of them are subclinical. The exact number of larvae necessary to produce disease in man is not known. There are some interesting experimental observations, however, which indicate that the severity of the reaction to the same dose varies with the species of host, but that within a species, size of dose is an extremely important if not the principal factor in determining the severity. For instance, rats tolerated without demonstrable ill effect doses of 10 to 20 larvae per gram, but are nearly all killed in 12 to 35 days by doses of 40 gm. and in two to seven days by 70 gm. (McCoy, 1931). Swine, on the other hand, while not injured by less than 1 gm. were all made ill by as little as 1 to 4 gm., and at this dose 8 of 14 died in 7 to 24 days (Schwartz, 1938). Even one larva per gram would mean between 60,000 to 70,000 larvae for a 150 pound man, which would require the eating of more than 150 pounds (60-70 kg.) of infected pork since rarely do hogs, i.e., garbage-fed hogs, have as many as one larva per gram of meat.\* It seems probable then that man is injured by these worms much more even than swine, but unless man is more than a hundred times as susceptible, he would rarely ingest enough infected pork at one time in the United States to suffer from trichinosis. This is in accord with the finding that individual clinical cases or more extensive outbreaks are always traced to concentrated doses of infective larvae.

The light infections harbored by so many Americans may not be without some benefit in terms of immunity. Ducas in 1921 first reported that a protective immunity develops in rats as a result of a single infection, and this has been verified and amplified by many workers. McCoy has shown that as low an initial dose as two or three larvae per gram will stimulate a demonstrable immunity, and that 1 to 20 larvae per gram will protect a rat from several times the otherwise lethal dose. There is some limited evidence that an initial infection in man will confer complete protection for at least months thereafter. Such protective immunity may not prevent some clinical manifestations from exposure to reinfection. An immunized animal, upon receiving a subsequent challenge dose, may develop allergic manifestations characterized by pronounced edema of the intestinal mucosa with resulting diarrhea, although none of the worms from the challenge dose becomes established.

\* Although Mark, 1888, found much higher infections (10-100 larvae/gm. and one case with 15,000 larvae/gm.) in hogs fed on meat trimmings from the abattoir as well as kitchen garbage, no infections of this intensity have been reported since in swine.

ch a condition in man may be classified as "intestinal flu," food poisoning, or receive some other nonspecific classification.

Although trichinosis is commonly ushered in with a gastro-intestinal episode, the earliest physical sign which points to the nature of the disease is commonly angioneurotic edema of the upper eyelids; this is commonly followed by muscular tenderness and pains; an eosinophilia is characteristic and suggestive. A variety of other signs and symptoms may develop, such as bronchopneumonia (about 15 per cent according to Minot and Rackemann, 1915), transient neurological signs, and myocarditis. Only the myocarditis may leave permanent damage, but even that clears up completely unless the damage is severe. The failure to find larvae in the blood and spinal fluid is meaningless since even at the height of the migration they cannot be regularly detected. Bachman (1928) developed an intradermal test, using a saline extract of the trichina larvae, which has proved to be very useful. The test usually is not positive until the second week of the infection and the recovered subclinical case may be positive for years. The precipitin test is usually positive only during the active infection but, unfortunately, does not become positive regularly until the third week of the infection. Only the closely related *Trichuris trichuria* regularly produces a nonspecific or cross reaction with the intradermal test. In areas where this infection is common it is important to check the validity of the positive intradermal test by repeated stool examinations for *Trichuris* eggs.

**TREATMENT.** Treatment is largely symptomatic, including rest. Harwood and Cutler have shown that calcium salts will relieve the toxicity of tissue destruction but do not alter the course of the infection in rabbits; its possible value in human trichinosis has not been demonstrated as yet. Most attempts at specific therapy have been useless, but not infrequently they have contributed unfavorably to the disease. Recently Oliver-Gonzales and Hewitt (1947) have found that hetrazan given very early in the course of experimental infections in rats may reduce the number of worms ultimately developing but its possible value in human trichinosis is yet to be demonstrated.

**PREVENTION.** The procedures for the prevention of this infection may be classified under two main headings, individual and community, or personal and public.

At least for the present it is of fundamental importance to stress the role of the individual in the prevention of disease. Until such time as there is universal abstinence from the currently common practice of feeding raw garbage to hogs, there can be no assurance that any particular hog is free of the infection. Accordingly, in the United States only the individual can insure his own protection by making certain that any fresh pork he or she eats is adequately cooked. Carefully controlled experiments have shown that all trichina larvae are quickly killed at  $50^{\circ}\text{C}$  ( $131^{\circ}\text{F}$ ) and instantly killed at temperatures less than  $60^{\circ}\text{C}$  ( $140^{\circ}\text{F}$ ) (Ransom and Schwartz, 1919; Otto and Abrams, 1939). Either higher temperatures or continued exposures to these temperatures are required to give the meat a cooked appearance. Thus, any fresh pork which has lost its natural pink color and has turned gray or brown with cooking would contain no living trichina larvae. The difficulty, however, comes from the fact that it may take some little time for heat to penetrate to the center of a piece of meat. Frying or roasting particularly tend to produce an insulating layer, the brown crust, so that a large roast which



looks well done may be pink and infectious in the center. Although fresh sausages are usually small, quick frying will even more quickly produce an insulating layer on the outside. We have seen such sausages with a very hard brown crust containing a core of fresh uncooked meat. This is apparently why fresh pork sausage is so commonly the source of infection. The same admonition applies not only to pork but to the flesh of any carnivorous or omnivorous animal, such as the bear.

Community or public activities in control of trichinosis should center on the prevention of infection in the animal which is the primary source of infection for man. Certainly in the United States and probably in most areas other than the Arctic or Nearctic regions pork is the principal source of infection. The principal source of the porcine infection in *all areas* of the world where it has been studied is raw garbage or other meat scraps in feed lots and fattening pens *before* the animals are brought to the abattoir for slaughter. Either uniform state regulations or federal regulations are, and have for many years, been so obviously needed for the control of garbage feeding that one is forced to wonder why they have not been established. The initial and anticipated operating costs and fear that cooked garbage will be less nutritional for hogs has resulted in active and organized resistance by some garbage feeders to such legislation. It should be noted that the provisions in England and Canada for feeding only cooked garbage has not brought financial ruin upon the swine industry in these countries and has offered significant protection. Continued lapses in the enforcement of the laws in a few instances in Canada has resulted in trichinosis. The recent evidence that vesicular exanthema and perhaps other virus diseases of swine are spread through the feeding of raw garbage has been more effective than the evidence that it is the basic source of human trichinosis in curbing this practice. At least 41 states now have laws or regulations requiring the cooking of garbage used as swine feed.

Other public measures, however valuable in themselves, must be considered as auxiliary measures, even the present federal regulations on heat and cold processing and the continental practice of microscopical inspection of pork. Present federal regulations apply only to pork products which are "customarily eaten in the form in which they are purchased." The regulations are based on carefully conducted experiments and as indicated above it has since been demonstrated that "processed pork" products do not contain living trichina larvae. Such products as wieners, smoked sausage, and even smoked hams commercially prepared either in federally inspected or noninspected processing plants are almost invariably safe for consumption. Although it is possible that some trichina may escape destruction in such products as smoked hams, in which the curing process may be shortened, it is hardly conceivable that enough to produce disease would survive. Federal regulations covering such pork products are set forth under three main headings. (1) In heat curing, all parts of the meat must reach a temperature of 137° F. (2) In cold curing, meat must be held at temperatures of not higher than 5° F for less than 20 days; -10° F for not less than 10 days, or -20° F for not less than six days. More recent studies have indicated that much shorter time at lower temperatures are equally effective (Gould and Kaasa, 1949) but they are not yet written into the regulations. (3) Special curing methods include drying, salting and smoking under sharply specified conditions. It is significant to note that these conditions do not exceed the procedures commonly in use in curing the various dried or smoked pork products.

Recent work has shown that gamma rays will render trichinous pork noninfectious and safe for human consumption. However, its practical value is debatable.

Microscopical inspection of pork for trichina is routinely practiced in Germany and Denmark and locally elsewhere in Central Europe. Such federal inspection was maintained in the United States from 1892 to 1906 for pork intended for export. As Schwartz points out, this was an economic rather than hygienic measure. At no point was serious consideration ever given to its general application in the United States. Although it is commonly believed in Germany that inspection is responsible for reduced human infection, the data are not without ambiguity. For instance, files, 1901, traced 32 per cent of more than 6,000 cases of trichinosis to pork which had passed the German Government Inspection. Deaths from trichinosis still occur in Germany. Thus, the view, both scientific and official, generally held in the United States is that microscopical examination of pork would give a false sense of security. Schwartz (1941) has estimated that the cost of this false sense of security would be about \$10,000,000 a year, almost twice the cost of all other meat inspection combined. It may be noted also that only about 60 to 70 per cent of the pork killed in the United States is killed under federal supervision.

Thus, the two points to be emphasized are: (1) do not eat the fresh meat of dogs or any other omnivorous or carnivorous animal without thorough cooking, i.e., until the natural pink color turns to gray or brown in all parts of the meat; and (2) take advantage of the swine industry's concern over the spread of swine diseases by raw garbage feeding to support the extension and enforcement of laws and regulations against this practice.

**The Beef Tapeworm.** *Taenia saginata*. *Taenia saginata* occurs as an adult tapeworm only in the intestine of man. The larval stage, or bladder worm, known as *Cysticercus bovis*, occurs only in the tissues of cattle and produces a condition known as "measles" in beef or "measly beef." The infection in man may be more common than is generally realized. Penfold \* reports that it was the only large tapeworm of man in Melbourne, Australia, and through painstaking efforts found many unreported infections. It is by far the commonest of the large tapeworms of man in the United States but it is even more common in Mexico. However, it occurs to even a greater extent in other beef-eating countries. It is reported to be particularly common in Syria, Africa, and parts of the subcontinent of India among Mohammedans, who customarily eat beef raw. In Baltimore the tapeworm is found in man most commonly among the professional group or other higher economic groups, such as the legal profession, and business personnel. The possible significance of these limited observations is not clear. It may be that the higher economic groups are more likely to seek medical attention for minor complaints or that such groups eat the better cuts of beef and thus more commonly eat them raw. Intestinal discomfort, particularly epigastric pain, occurs during the course of the development of the worms and apparently is more severe about six or eight weeks after infection when the worm is maturing. Thereafter most infections may be asymptomatic except for episodes of gastric distress. These are most likely to occur when a meal has been delayed or missed and may give rise to giddiness

\* The careful studies of Penfold and his collaborators on the biology, epidemiology, control and medical aspects of *T. saginata* infection are reported in a series of papers from 1935 to 1938 in the Medical Journal of Australia and the Journal of Helminthology.



at those times. The Australian workers could find no evidence in support of the common belief that the worm causes chronic hunger, massive appetites, or failure to gain weight. It does not produce anemia or any other constitutional symptom.

Man is infected exclusively by the eating of raw or rare beef containing the living cysticerci while cattle are infected by the ingestion of feces or food or water contaminated with feces from infected humans. Meat inspection as practiced in the United States has disclosed scarcely more than 0.1 per cent infection in cattle. However, the infection is far from uniformly scattered. Sussman and Prechal (1950) have recently shown an average of 3.0 per cent infection in cattle fattened in the feed lots of the Salt River Valley in Arizona but much of this infection was in the cattle from one ranch which had an infection rate of 12 per cent. Very often the cysts are dead and calcified. In an experience with a herd of 900 cattle harboring 10 to 25 per cent infection practically all the cysts were calcified. Penfold has shown that the cysticerci in the tissues of cattle live only a matter of months, usually not more than two or three months, and have begun to calcify within six months. Even the calcium is resorbed within two to three years. Furthermore, cattle once infected are immune to reinfection, at least for a matter of years thereafter. For instance, cattle grazed continuously for two years on pasture fertilized with raw human sewage harbored no living cysticerci, although it was shown that most of the cattle became infected. It was accordingly recommended that no attempt be made to curtail the dumping of sewage in pastures but that where such practices exist in Australia the calves be intentionally exposed to the heaviest source of human feces to insure early infection and not slaughtered under two to three years thereafter. It is visualized that at the end of three years, even the calcified cysts will have become resorbed. It seems probable that this method of control alone could do no more than provide a biological balance and could not be expected to completely break the chain of transmission. Certainly it has no application in the United States since the source of infection in cattle is the careless defecation, as Sussman has shown, by relatively few infected individuals. Such individuals may habitually or intermittently defecate in pastures, drainage ditches, feed lots, and even in silage tanks. The prevention of infection in cattle in the United States is a simple matter of educating cattlemen and cattle handlers of the necessity of enforcing simple sanitary concepts. The examination of all help and the treatment of the infected individual has proven of value; the greatest value, perhaps, results from the collateral discharge of noncooperative personnel.

Since the source of infection in cattle is individual and not readily controlled by community activity it is necessary to have inspection of beef. Since the cysticerci are readily visible to the naked eye and are concentrated in the heart and the region of the heart, gross inspection of the carcass as practiced in federally supervised abattoirs is a comparatively simple and effective method of eliminating infected beef. While inspection cannot give absolute assurance of protection, the difficulty arises primarily from the fact that about one-third the cattle in this country are slaughtered without benefit of federal inspection and local inspection regulations are quite varied and in general unsatisfactory. Thus, absolute protection from infection, particularly if the inspection status of the meat is unknown, depends upon the handling of meat. The principal source of infection appears to be raw meat

ut rare beef cannot be eliminated. The cysticerci are killed quickly at 55° C (131° F) and within a month by freezing.

In conclusion, it seems desirable to emphasize again that the problem is simply one of the adherence to the elementary principles of fecal disposal—the provision of easily available privies near cattle lots and the enforcement of their use.

**The Pork Tapeworm. *Taenia solium*.** This tapeworm has a life history essentially the same as that of *T. saginata* except that pork replaces the cattle in the above life cycle. The cysticerci in pork produce “measly pork.” It is, however, a greater danger to man because of the fact that man may play a dual role. Man is normally the host for the adult tapeworm in the intestinal tract and pigs for the larval stages (*Cysticercus cellulosae*) in the muscle of that animal. However, when the eggs of *T. solium* from man are ingested by the same or another human the larval stages may develop in a manner somewhat similar to that in the pig. However, man is an abnormal host for this stage and accordingly there appears to be a wider dissemination of these larvae in the tissues of man beyond the musculature than is the case with the pig.

Thus, *Cysticercus cellulosae* in man may commonly involve the central nervous system and be the source of serious disturbance, including the manifestations of Jacksonian epilepsy. It is perhaps important to note that even here the cysts die early and are calcified so that if the patient recovers from the acute manifestations he usually is thereafter without any serious impairment. There has been a great deal of confusion on the source of human infection with this larval stage and not infrequently time is wasted in looking for the parent worm in the intestine of the same individual. No evidence has been presented to support the statement that internal auto-infection with *Cysticercus cellulosae* results from an adult tapeworm in the intestine, and it is difficult to visualize such a process. Man may become infected with cysticerci by ingesting eggs in his own feces but probably more commonly obtains them from eating contaminated food. Thus, we find this infection with the larval stage most common in areas where widespread fecal contamination occurs including areas where human feces are used for fertilizer. It became a problem with certain regiments of the British Army some years ago. There have been a number of cases of *Cysticercus cellulosae* infection reported in the United States, many of which, however, were acquired outside of the country. In this hemisphere the infection in both adult and cysticercoid stages is more common in Mexico and points south, and is fairly common in Mesopotamia on the other side of the world. Again, although freezing, heating, or various processing will kill the larval stages in pork, they are so readily visible that federal meat inspection includes direct examination for them just as it does for *Cysticercus bovis* in cattle, and federally inspected pork may be considered to be free of this infection although it may not be free of trichina. As already noted a significant portion of the swine is killed outside of federal inspection and this constitutes a potential hazard of infection.

As with *Taenia saginata* the prevention of infection is basically one of proper fecal disposal. Care of the disposal of human feces in and around swine raising establishments will prevent infection of swine. Furthermore, the feces of humans infected with *Taenia solium* are the direct source of *Cysticercus cellulosae*, the larval stage of this tapeworm, in man.



**Hydatid Disease. Echinococcosis.\*** Hydatid disease is caused by the larval stage of a tapeworm, *Echinococcus granulosus*. The adult is a small tapeworm, with only three segments and a total length of 3 to 6 mm., which lives in the intestine of dogs or related carnivores. The larval stage or hydatid develops in the liver of a number of domesticated and wild ruminants and even in the rabbit, but sheep are by far the most important host of this larval stage. The larval stage, i.e., the hydatid, is not only larger than the adult stage, but develops slowly and seems to have an almost unlimited capacity for growth and asexual reproduction, by budding. Carnivores are infected by eating the larval stage with the livers of these intermediate hosts. Man is infected as are the sheep or other intermediate hosts by ingesting the eggs from the feces of the carnivores. Thus, man is a blind alley intermediate host since carnivores have normally no chance of eating the infected liver (or other organs) of man. This was formerly a very important endemic disease in Iceland and has been an important disease in New Zealand and Southern Australia for many years. It is of growing importance in the sheep raising areas of Argentina, Paraguay, and Uruguay. It also occurs in widely scattered parts of Europe and in Siberia, the Near East, Asia, and the southern tip of Africa. It is a highly endemic infection in man only where the sheep-dog-man contact is intimate and common. The infection has apparently not become established in domesticated animals in the United States and Canada. The larvae have been reported in swine and cattle livers, up to 12 per cent in some lots of swine, and have even been found in sheep. However, the adult has been found less than half a dozen times in dogs. However, over 20 years ago Riley demonstrated that this parasite occurs as an endemic sylvatic infection in Minnesota, involving the moose and the timber wolf. Recently it has been shown that the sylvatic infection is common in northwest Canada and in Alaska. However, there is no evidence that this sylvatic infection has ever produced any center of infection in domestic dogs and sheep, cattle, or swine. Thus, while over 500 human infections have been found in the United States and Canada, over 95 per cent are directly traceable to endemic areas abroad. Magath (1937), in reviewing the 482 cases up to that time, found that 460 of them had previously lived in endemic areas abroad. The remaining 22 had never been outside of the continental limits of the United States or Canada and must thus have acquired infections within one of these countries. It is not known whether the sources of these infections were wild carnivores or undiscovered infections in dogs. Since Eskimos in Alaska have apparently acquired hydatid from their sledge dogs, there is increasing concern over the possibility that dogs brought from Alaska may become the source of human infections in the United States. The extent of this possible danger has not been determined and should be investigated (Magath, 1954). The disease develops slowly; more commonly than not the subject is asymptomatic for 10 or more years after becoming infected so that it is almost impossible to pinpoint the individual source of infection.

The control and prevention of human infection centers around preventing the infection of dogs. This has been dramatically accomplished in Iceland where a century ago there was over 15 per cent human infection, essentially 100 per cent infection in sheep and cattle, and over 25 per cent of the dogs harbored the adult

\* *Echinococcus* is conveniently treated here with the other tapeworms although man does not contract it by eating meat.

orm. Now (Dungal, 1946) autopsies have failed to reveal any infections in those under 20 years of age (Table 23-1).

Table 23-1. *Echinococcus* discovered at autopsy in Iceland (Dungal, 1946)

Age	Number of Autopsies	Cases of <i>Echinococcus</i>	Per Cent Positive
0-20	239	0	0
20-30	193	1	1
30-40	199	1	1
40-50	170	4	2
50-60	179	13	7
60-70	153	21	14
70-90	98	20	20
TOTAL	1,231	60	45

Only in those over half a century old was any appreciable infection found and was highest in those approaching the century mark. Of the 60 cases, 34 were males and 26 females. The dramatic reduction has been accomplished by the education of the people and enlisting their cooperation in instituting control procedures. The practice of feeding viscera of slaughtered animals to dogs has stopped and every effort has been made to destroy the carcass of any sheep which dies. This has been facilitated by a shift from home slaughter and slaughter in small community abattoirs to the utilization of large central abattoirs from which dogs are restricted. Accidental infection of dogs has been further reduced by a marked change in age of animals slaughtered for food. A century ago older sheep (three to four years old), with hydatids sufficiently developed to be infectious for dogs, were the commonest source of mutton whereas today five- to six-month old lambs constitute the bulk of the sheep slaughtered. Even if such young animals are infected the hydatid is likely to be acephalic (immature) and noninfectious. When the organized control program was initiated it included the annual treatment of all dogs with a powerful taenicide and the regular use of such treatment (Arecoline hydrobromide) still continues. Whether or not this is a continuing necessity appears not to have been determined but one would hesitate to discourage the practice until it is clearly demonstrated to be unnecessary.

In Australia, also, attention to preventing infection in dogs has brought a reduction in human infection. This is most evident in the City of Melbourne where stray dogs, with free access to multiple small abattoirs, were formerly 100 per cent infected but now constitute no serious hazard to man. This change was accomplished by consolidation of the abattoirs and the enforcement of restrictions on dogs around such abattoirs together with the impounding and killing of stray dogs. In the smaller towns and less populated rural areas progress has been slower but attention continues to be focused on unprocessed sheep offal and the destruction of sheep which die on the range. Thus control is basically a matter of not permitting dogs under any circumstance to have access to the raw viscera of any of the intermediate hosts, but primarily of sheep; and the destruction of stray dogs.



## FISH

In nutritive properties, there is little difference between the muscle of fish and that of beef. In other words, fish is meat although ordinarily not so regarded. Drummond found that the coagulable proteins of muscle tissue of the cod, herring and canned salmon have a nutritive value as high as those derived from beef. Fish also resembles meat in that both are poor in vitamin B.

The percentage of fat in different species of fish varies greatly. The unique quality of fish oils as a source of vitamins, especially A and D, suggest the importance of fish in the diet. The livers of fish do not serve as a storehouse of glycogen as do the livers of mammals, but are loaded with fat. All liver oils from fishes thus far studied are excellent sources of growth-promoting vitamins. The liver of the cod is a veritable storage battery of radiant energy, which gives to cod liver oil its well-known antirachitic properties. Some of the fat-rich sea fish, such as sardines, salmon and shad roe, have an energy value equal to that of hearty foods such as veal, milk, sirloin steak and baked beans. Salt-water fish and shellfish generally contain much iodine and are prophylactic against goiter. Fish also are fair sources of various mineral elements.

Fish poisoning or *ichthyotoxismus* is most frequent in Russia, Japan and the West Indies, and other seacoast countries in which fish forms a large part of the diet. It occurs especially in warm countries.

**Physiological Fish Poisoning.** Some fish are always poisonous, that is, normally contain a substance toxic to man; usually the poison is developed only during the spawning season. Various species of the *Tetrodon* and *Diodon*, which include the puffers, balloon fish and globe fish, frequently cause serious and fatal poisoning in Japan. The most poisonous is perhaps the fugu. In Tokyo alone, 680 fatal cases out of 933 were reported as occurring from 1885 to 1892 from the so-called "*fugu*." In China and Japan such fishes are sometimes taken for suicidal purposes. The active principle in fugu poisoning resembles curare. The poison is found mainly in the head, liver and ovaries, and called "*fugin*." It is not destroyed by boiling. Its chemical nature has not been determined. The symptoms produced are: dyspnea, cyanosis, dilatation of the pupils, relaxation of the sphincters, paralysis of speech, dizziness, salivation and vomiting. Death may result in one or two hours.

Few fish containing physiological poisons are found outside of the tropics. Some fish, such as shad and smelts, are preferred during spawning season. However, during spawning season the roe of different members of the sturgeon family, of the pike, and the barbel have been said to cause pronounced and even fatal intoxication; the symptoms resemble those of gastro-enteritis. Anchovy belassa and the meltite of the Indian Ocean are both said to be poisonous, the former causing death when only small amounts are taken, the latter causing violent vomiting. The Greenland shark causes an intoxication in dogs similar to that caused by alcohol. A certain degree of tolerance can be produced by feeding graded amounts. The roe of the European barbel produces the so-called "*barbel cholera*," while the roe of the pike is said to be poisonous during the spawning season. The toxic symptoms are said by Pozzi-Escot to occur in not less than 24 hours after ingestion. The smooth puffer (*Lagocephalus levigatus*) is considered by fishermen to

are the most poisonous of the fishes of Brazil. Little is known concerning the nature of physiological fish poisons.

**Bacterial Poisons.** Bacterial poisoning from fish occurs. The fish may be diseased, or when caught may be healthy, but the bacteria gain access and grow throughout the meat as the result of contamination or imperfect preservation. Bacterial diseases among fish are rather common and often occur as epizootics. In almost all the reported instances of injurious action resulting from bacteria the fish has been eaten raw. Bacteria may form poisonous substances in fish closely resembling botulinus. Fish caught by the gills in nets die slowly and decompose rapidly. They are of inferior flavor and value and are more liable to be injurious than fish taken from the water and killed at once; under such circumstances they remain firm and retain their flavor longer than those that die slowly. In some parts of the world live fish in tanks are offered for sale in the markets. This procedure cannot be commended from a sanitary standpoint, for the tanks are likely to become dirty and the fish liable to sicken and die slowly, so that the object of surveying only live, fresh, and wholesome fish is largely defeated. It is well known that fish decompose readily and should, therefore, be handled in a cleanly manner and used as fresh as possible. When refrigerated the temperature should be low. Frozen fish keep well.

"Fish poisoning" is doubtless sometimes due to a toxin produced by *Clostridium botulinum*, or a similar anaerobe. Poisoning from fish contaminated with *Salmonella* or one of the closely allied members of the colon-typhoid group is very seldom recorded. Allergy to fish is rather common.

**The Fish Tapeworm, the Broad Tapeworm of Man (*Diphyllobothrium latum*).** This is the only tapeworm of man which is acquired through the eating of raw or insufficiently cooked fish. It has a complex life history. The adult tapeworm, which may be up to 30 feet or more long, lives in the alimentary canal of man and a number of fish-eating carnivores and omnivores. The egg, when reaching fresh water, hatches, releasing a free-swimming larval stage known as coracidium. These, when eaten by certain of the small crustaceans of the genus *Diaptomus* (Cyclops), develop to the next larval stage known as the proceroid. The third larval stage, the plerocercoid, develops in the muscles of fish which have eaten the *Diaptomus* containing the proceroid. The plerocercoid of these small fish are capable of developing if eaten uncooked by man or some other definitive host. However, most human infections are acquired from eating a larger fish, a transfer host, which has acquired the plerocercoid stage in its muscles as a result of having eaten a smaller infected fish.

The disease is most highly endemic on both sides of the Baltic coast but is particularly common in Finland, where 10 to 15 per cent of the population is infected. It occurs, however, elsewhere in Europe particularly in the Danube basin and around the Swiss lakes. It has been imported into the United States in the Great Lakes region and into Canada as far north as Lake Winnipeg; apparently imported by the Finnish population which has moved into those areas. Recently Summers and Weinstein (1943) found evidence of a small center in Florida. Somewhat over 100 cases have been reported from the northern lake regions and are largely divided into two groups. The first group are the native Finns who continued their habit of eating raw fish. The second group are Jewish housewives. Macbeth has



studied the latter group in Winnipeg, Canada, and traced the infection to the preparation of gefüllte fish which they are accustomed to taste raw in the process of seasoning. Similarly there are reports of its occurrence in Jewish housewives in New York City from fish shipped from the Great Lakes region.

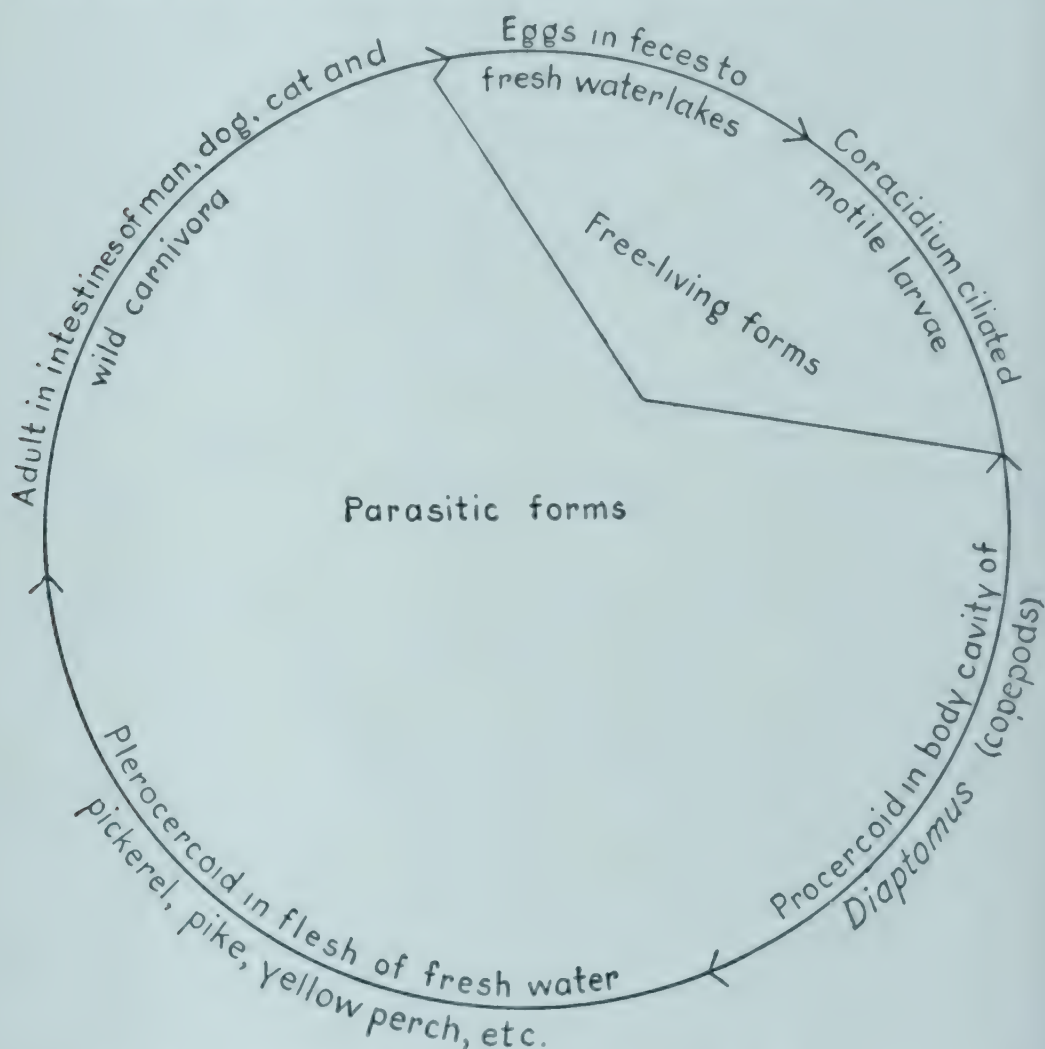


Fig. 23-1. Life cycle of *Diphylobothrium latum*, the fish tapeworm.

This tapeworm infection has long been associated with macrocytic anemia, and it is not impossible that it is at least a precipitating factor in the production of such anemias. Often the anemia reported is absolutely indistinguishable from the so-called pernicious anemia. Birkeland (1932) has suggested certain differences between the classical pernicious anemia and that associated with some of the fish tapeworm infections. He notes, however, that there are relatively few cases of this anemia compared to the population of infected Finns, and calls attention to the fact that it is rare or absent among the infected individuals in this country. It is possible that this worm may provide a precipitating factor in the production of the disease but it has never been demonstrated that it actually causes the anemia.

The most obvious control procedure is the thorough cooking of all fish eaten. However, freezing at temperatures around  $1^{\circ}$  to  $10^{\circ}$  C for at least 24 hours is sufficient to kill the plerocercoid stage. This procedure could perhaps be utilized

When fish are stored or shipped under refrigeration, by merely dropping the storage temperature. However, since fish are rarely eaten raw in this country this may prove to be a costly way to serve relatively few people. Inspection of fish for the plerocercoid stage is impractical on two grounds. It would require cutting the fish open and thus destroying their saleability and, furthermore, they harbor the plerocercoid stage of a number of other worms which are not infectious for man but which would be mistaken for, in fact are indistinguishable from, the plerocercoid stage of *D. latum*.

Since man is the most effective host for the adult stage, it may be that man constitutes the principal source of infection for the various aquatic organisms coming up with the fish which are eaten by man. Thus, the adequate disposal of fecal material is important. Although the eggs may survive passage through sewage and constitute a localized source of potential infection when emptied into fresh water, the direct deposition of feces into water from open privies is also an important source of infection. It would, however, be inadequate to consider that man is the only possible source of infection. While the worms in dogs frequently never pass eggs or only very few eggs, Vergeer (1930) has concluded that both dogs and the brown bear constitute important sources of infection for the aquatic intermediate hosts. The problem warrants further study but, unlike many other parasitic diseases, it seems probable that we cannot approach the question of control only in terms of fecal sanitation and must have recourse to the processing of the fish which is eaten by man. Cooking offers the only guarantee against infection.

**TREMATODES.** A number of the trematodes of man are acquired by eating raw fish. However, a number of them including the schistosomes are not acquired in this manner. Therefore, the group is not discussed at this place, but the reader is referred to the trematode diseases (page 574).

### SHELLFISH

Shellfish include mollusks, as oysters, clams, mussels; and crustaceans, as lobsters, crabs and shrimp. When we eat clams, oysters and soft crabs, we take the entire animal except the shell. This insures the consumption of unrecognized food substances which may be important supplementary factors in our diet. Oysters contain vitamins A, B and C; they are rich in B. Clams contain vitamin B but not in appreciable amounts. They also have less A, but more D than oysters. Oysters are excelled only by liver in the amount of iron and copper which they furnish in an average serving. The protein compares favorably with the protein of other meat products. Shellfish are rather poor sources of fat and carbohydrates. Sea foods are of special significance in that their iodine content is higher than that of land plants or animals. They are nutritious, savory and digestible, and are important additions to the diet.

The conditions which render such food injurious are much the same as those discussed in connection with fish. No disease of shellfish is known to affect man. Snails convey flukes, but not by ingestion. Shellfish may be perfectly good and wholesome when fresh, but may become contaminated and injurious on keeping, especially if not properly preserved. It is seldom that they are responsible for illness, albeit they have a bad reputation. This is due in large part to the fact that



allergy (atopy) to these foods is rather common. In such instances the trouble is not with the food but with the person who eats it.

Man has made shellfish a danger to himself by polluting the water in which they live. With the growing pollution of tidal and inshore waters, clean beds for growing and collecting oysters and other mollusks have become a real health problem. On being transferred to clean water, shellfish may in time purge themselves of typhoid and other injurious bacteria. In this group, oysters and clams are the most important vectors of intestinal infections because frequently eaten raw.

**Oysters.** An active oyster in the combined process of breathing and feeding "drinks" daily many gallons of water through its gills. The food particles sifted by the gill are caught on the inner surfaces, which are coated with a mucous layer and which, actuated by cilia, move like an endless belt and convey the food particles into the funnel-shaped mouth. From the mouth, food enters the sac-like stomach cavity and passes through the short gut, reaching the cloacal or gill effluent chamber, and is ejected some five hours after entering the shell. Bacteria reaching the tissue surfaces have a tendency to elimination through the feeding function. In the language of the fisherman, floating is usually spoken of as "drinking," "plumping" or "laying out." This gives the oyster a chance to purge its intestinal tract. Such oysters are cleaner and keep in better condition for shipment. There is a sanitary advantage in floating oysters provided the water be clean. The health hazard, however, is great because of the difficulty of finding satisfactory inshore water.

Oysters are most active during the warm summer months, drinking large quantities of water, and they therefore contain more bacteria then. When the temperature falls activity lessens; the shell closes at  $7.2^{\circ}\text{C}$ , when the oyster passes into an inactive condition, a sort of hibernation. The bacterial population of oysters is therefore seasonal.

**NUMBER OF BACTERIA.** Oysters are apt to reflect the bacteriology of the water in which they live. Bacteria are found both in the oyster and in the oyster liquor. Oysters from clean water contain few bacteria and no *E. coli*; oysters from polluted water usually contain many bacteria and numerous *E. coli*; although the reverse occurs. The number of *E. coli* is determined by a method of the American Public Health Association (1922).

The bacterial content of the water in which oysters are raised has a direct influence on the content of the shell liquor because oysters drink large quantities of water, from which they obtain their food. When tests of samples of oyster-shell stock or shucked oysters show a most probable number of 230 or more coliforms per 100 ml. of stock sampled at the growing area, unfavorable conditions or practices are indicated. Occasional estimates of 2,400 coliforms per 100 ml. may be tolerated but corrective measures should be taken immediately when this occurs in more than two consecutive samples.

**TYPHOID BACILLI.** Oysters from polluted waters may retain the typhoid bacillus for a long time. When placed in clean water the numbers rapidly decrease, so that the hazard from this source diminishes. The time of purification depends upon the temperature and purity of the water and its amount. Repeated changes of fresh water result in a rapid diminution, reaching about 99 per cent after three changes of water.

Krumwiede and others (1926) call especial attention to the prolonged persistence of minimal numbers of *S. typhosa* under different conditions. They state that apparently the only safe oyster is one which has been protected from contamination by fecal pathogens for at least some months prior to harvesting. They found *S. typhosa* to persist in shell oysters stored at refrigerator temperatures for 49 days, though the oyster died on the forty-first. On shells of stored oysters the bacilli apparently are dead after 14 to 40 days. A dead oyster serves as a culture medium and the number of *S. typhosa* will increase if the temperature is satisfactory.

Jordan (1925) found that the longevity of *S. typhosa* in the oyster juice of both shucked and shell oysters in storage varies with the temperature. In general, the temperature best suited for the preservation of the oyster tends to prolong the life of typhoid bacilli in the oyster. He found them to survive 22 days in shucked oysters and 60 days in shell oysters. In living shell oysters during dry storage at 45° F, typhoid bacilli survived for a longer period than the oysters. Kinyoun (1925) aroused oysters from hibernation, fed them with *S. typhosa*, and then stored them. *S. typhosa* was recovered 15 days after the oysters had been fed with the organism, when the feedings were discontinued.

Park states that *S. typhosa* persists in hibernating oysters much longer than in oysters that are actively drinking. Krumwiede and others (1926) isolated *S. typhosa* 14 days after contamination and return to natural waters of low temperature.

The transfer of oysters from a polluted water to a clean water may result in a marked and rapid drop in the number of bacteria, if the oyster drinks freely in the clean water. Krumwiede and others (1928) found that if oysters contaminated with *S. typhosa* are planted in natural waters during the warm months, *S. typhosa* cannot be isolated after 14 days. In sea water, *S. typhosa* may persist in small numbers for 19 to 24 days. Evidently this procedure cannot be relied upon to render oysters safe, especially during the colder months. The Health Department of New York City permits the transfer of oysters from doubtful to clean waters only during the closed season. The oysters must remain there at least 30 days. Such conditioning of oysters and wet storage should be allowed only when pure water of proper salinity is available.

*Oysters and Typhoid Fever.* Typhoid fever and other intestinal infections have been convincingly traced to infected oysters. They may be infected when dredged from sewage-polluted beds in which they live and grow. In practically every instance, however, that typhoid fever has been traced to oysters, infection has occurred through the process of floating or storage rather than from the oyster beds.

An epidemic of typhoid due to shellfish was reported by Pasquier in 1816. The oysters were floated in the moat of an old castle used for sewage disposal.

At Middletown, Connecticut, Professor Conn showed that the outbreak of typhoid fever at Wesleyan University during 1894 was due to raw oysters eaten at fraternity banquets. This is one of the pioneer classics in epidemiology. The evidence is convincing; the conditions were those of a planned laboratory experiment. Since then, many outbreaks have occurred (see page 198).

In Great Britain more than in other European countries, shellfish transmission of typhoid fever is regarded as quite frequent. In 1896, Newsholme, then health officer in Brighton, published careful studies showing that 30 per cent of the typhoid infections occurring in that city were due to oysters and other shellfish. For Belfast,



the investigations of Mair showed that the extensive increases of typhoid fever from 1897 to 1909 were due in a large measure to infection from cockles gathered along a shore not far from the main sewer outlet.

Fuller reviewed the literature on this subject which covered more than 20 separate outbreaks due to infected shellfish up to 1904.

**THE NEW YORK EPIDEMIC OF 1924-25.** The widespread epidemic of 1924-25 (Ramsey and others, 1928), which radiated from New York, exceeded in magnitude any heretofore recorded. As a rule typhoid outbreaks involve few people in a limited area, but this one involved at least 1,500 cases and caused over 100 deaths. It followed the shipment of infected oysters for a radius of much over 1,000 miles. It included New York, Washington and Chicago particularly; and there was an excess prevalence of typhoid fever probably due to infected oysters in Buffalo, New York; Cincinnati, Ohio; Grand Rapids, Michigan; Memphis, Tennessee; Pittsburgh, Pennsylvania; Providence, Rhode Island; Rochester, New York; Scranton, Pennsylvania; Yonkers, New York; and many other cities, extending even to San Francisco, California. The infected oysters were distributed between October 25 and December 20, and the disease prevailed three to four weeks later. This corresponds to the seasonal prevalence of oyster-borne typhoid, which occurs mostly in the fall and early winter. When oysters hibernate during cold weather they are less subject to contamination. The trouble was traced to oysters distributed by a producing company operating in the vicinity of West Sayville, New York, and it is probable that the oysters came from one bed or float and constituted a small proportion of the total.

**Prevention.** The safest rule would be to use oysters and shellfish only from clean water fit for drinking purposes. Not only should the oyster beds be clean, but special care must be taken to prevent contamination of the water in which oysters are floated because most oyster-borne outbreaks of disease have been traced to this source. Under these circumstances and with cleanly methods of handling, oysters are reasonably safe. If taken from doubtful waters, they should be purified by floating in clean sea water if available, otherwise chlorinated water.

Wells first called attention to the possibility of purifying polluted oysters in chlorinated sea water. The method is now used on a commercial scale. It is, however, impracticable to disinfect a live oyster with chlorine or any other germicide substance for the reason that if the chlorine water be strong the oyster closes up tight; in any case, the chlorine is soon used up. Chlorination, however, has a use, namely, to disinfect the water in which the oysters are floated. This is important because of the greater danger of inshore contamination. It gives a ready means of obtaining a safe water in which to condition oysters or for wet storage. By drinking and disgorging the purified water, the oysters tend to free themselves of bacteria. At least the danger of their picking up pathogens from the water is eliminated. The degree of purification following changing sea water approximates that observed with a similar treatment of chlorinated sea water. It is sometimes difficult to obtain clean sea water on shore without chlorination.

In view of the fact that oysters from sewage-polluted water may have a low score, the best index is the bacteriology of the water. This is not always practical. If the water be clean, the oysters will have a clean bill of health.

Oysters should be grown and dredged only from beds accredited on the basis

of a sanitary survey. This must be comprehensive and include a study of tides, currents and channels with reference to sewage pollution, as well as the bacteriology of the water and of the oysters at different points and different tidal times and seasons. The inshore oyster-houses or shucking plants, the water supply for drinking or wet storage, the fishing boats, personnel, toilet facilities, as well as refrigeration for shucked stock, must also be investigated.

Based upon the results of the survey, oyster beds should be licensed. Regulations should make it possible to trace shipments to their source. Prevention, therefore, needs official sanitary supervision of the industry.

Thorough cooking will kill typhoid bacilli and other nonspore-bearing intestinal bacteria sometimes transmitted by oysters.

Following the oyster-borne outbreak of typhoid fever of 1925, the U. S. Public Health Service undertook to make periodical surveys of the work of state agencies in charge of sanitation of shellfish areas. Based upon this work, lists of approved oyster shippers are published from time to time for the information of health officials in oyster-consuming states and cities.

**Other Shellfish. Clams.** There is epidemiological evidence tracing typhoid outbreaks to clams. That the infection may be so conveyed is clear, for clams are often collected from polluted beaches. Perhaps they are not frequently the cause of trouble because usually cooked before being eaten. The consumption of raw clams, however, is increasing. A few cases resembling mussel poisoning have also been reported.

**MUSSEL POISONING.** *Mytilus edulis*, the common mussel, is a source of poisoning in England and on the Continent, *M. californianus* on the Pacific Coast of the United States.

Three clinical types of mussel poisoning have been described: (1) erythematous, doubtless due to allergy; (2) enteric or intestinal, probably bacterial; and (3) paralytic, a toxemia.

Savage in 1918 summarized the cases reported in Great Britain, finding that from 1827 to 1909 there were 61 cases, eight of which were fatal, a case mortality of 13 per cent. A notable example of mussel poisoning occurred at Wilhelmshaven in 1885. A large number of dock laborers and their families were poisoned shortly after eating cooked mussels; three died. The mussels were examined by Brieger and Salkowski, who isolated several basic substances or "ptomaines," one of which, mytilotoxin, was poisonous to animals, causing similar symptoms.

A group of 102 cases with six deaths occurred in 1927 in San Francisco, California, as reported by Meyer and others (1928). In this outbreak the symptoms were peripheral paralysis varying from slight trembling and numbness about the lips to a complete loss of power in the muscles of the extremities and neck, and to death by respiratory failure. Symptoms in moderately severe cases came on in about 5 to 30 minutes, developing rapidly. Vomiting was inconstant and abdominal pains were not recorded. Muscular weakness increased so rapidly that within four to six hours the head could be raised only with great difficulty. The temperature was subnormal, pulse firm, slightly quickened. All those taken ill had eaten steamed, cooked or raw mussels of a Pacific Coast variety, *Mytilus californianus*, freshly gathered in different localities approximately 45 miles south and 50 miles north of the Golden Gate.



Subsequent to this outbreak, the studies of Meyer and his colleagues had contributed much to understanding this condition as it occurs on the Pacific Coast. Up to 1947, they had collected records of 409 cases of mussel and clam poisoning with 35 deaths. Most of the cases occurred along the central California coast. There were scattered outbreaks from Juneau, Alaska, to southern California and the Gulf of California, Mexico. There was a limitation to the seasonal distribution of these cases; they occurred between May 15 and October 26, the season of maximum risk was somewhat earlier in the southern than in the northern part of the coast. In 1936, the occurrence of cases of severe illness following consumption of mussels was observed in Digby County, Nova Scotia, on the Atlantic Coast (Gibbard and others, 1939). The poison found was similar to that which had been identified in California. It was recovered from two species of mussels, i.e., *Mytilus edulis* and *Modiola modiolus*. In a survey of commercially important shellfish areas of the region it was subsequently found that the poison could be recovered from shellfish only from the Bay of Fundy area in the late summer and early fall.

From the accumulated observations on the geographic and seasonal distribution of cases along the Pacific Coast, Meyer and his colleagues sought the causative factor in the food of the shellfish, i.e., the diatoms and the dinoflagellates. The poison was finally detected in and extracted from plankton (Sommer and others, 1937). The particular species of dinoflagellate finally identified as the source of the paralytic shellfish poison is *Gonyaulax catenella*. This dinoflagellate may multiply to such an extent that the water is a deep rust red color, so-called red water. It can be seen for miles in the daytime and is a beautiful luminescent spectacle at night. A method has been devised for detecting and quantitatively estimating the poison in shellfish. It consists in measuring amounts of alcohol soluble extracts of the livers of the shellfish by injecting mice peritoneally. The poison which chemically belongs to the class of alkaloids is one of the strongest known. It has been crystallized without losing its pharmacological activity (Dack, 1949).

*Prevention.* Mussels should be taken from clean water and handled with sanitary care to prevent bacterial contamination. The same principles that apply to oysters are applicable here. Cooking is prophylactic against this danger.

The prevention of the toxic form of mussel poisoning is based first of all upon the fact that the poison is seasonal. In California a quarantine is placed upon mussels and clams from June to September. The poison is thermostable. Cooking is not preventive, boiling does not destroy the poison. In the Wilhelmshaven episode, death occurred 15 minutes after eating boiled mussels. It has been found, however, that one-fourth ounce of bicarbonate of soda added during cooking for each quart of water used destroys 85 per cent of the poison in 20 to 30 minutes.

## EGGS

Perhaps no article of diet of animal origin is more commonly eaten in all countries and served in a greater variety of ways than eggs. Eggs are used in nearly every household in some form or other. It has been calculated that on an average they furnish 3 per cent of the total food, 5.9 per cent of the total protein, and 4.3 per cent of the total fat used per man per day.

When we speak of eggs we ordinarily mean hen's eggs, but the eggs of ducks

geese and guinea fowls are used to a greater or less extent; more rarely turkey's eggs and sometimes those of wild birds. Plover eggs are prized in England and Germany, while in this country the eggs of sea birds, such as gulls, terns, herons, and murre, have long been gathered for food. Other eggs besides those of birds are sometimes eaten. Turtle's eggs are highly prized in most countries where they are abundant. The eggs of the terrapin are usually served with the flesh in some of the ways of preparing it for the table. Fish eggs, especially those of the sturgeon, are preserved in salt under the name of caviar. Shad roe is also a familiar example of the use of fish eggs as food. The eggs of alligators, lizards, serpents, and some insects are eaten by races who lack the prejudices of western nations.

Large quantities of eggs are now broken out, mixed, frozen or dried. These products are largely employed by bakers and others who use eggs in quantities.

Hen's eggs vary considerably in size and appearance. The shell constitutes about 11 per cent, the yolk 32 per cent, and the white 57 per cent of the total weight of the egg. The eggshell consists mainly of carbonate of lime, and when freshly laid is covered by a mucous coating. The egg white consists of 86.2 per cent of water, 12.3 per cent nitrogenous matter, 0.2 per cent fat, and 0.06 per cent ash. The yolk consists of 49.5 per cent water, 15.7 per cent nitrogenous matter, 33.3 per cent fat, and 1.1 per cent ash. These are averages; different eggs vary somewhat in composition from each other. Hen's eggs average about 0.003 per cent of iron. It is noteworthy that eggs contain practically no carbohydrates and are poor in calcium. The chick gets its calcium by absorption from the shell.

**Nutritive Value.** The egg contains all the chemical complexes necessary for the formation of the chick during incubation. Eggs, therefore, furnish everything needed for the full development of the embryo. The egg is indeed a complete food, but not one which produces the optimum results when employed as the sole source of nutriment. There is an interesting contrast between eggs and milk. Aside from the calcium content of the white and yolk of the egg, which is much lower than that of milk, the contents of the egg resemble milk in a general way in nutritional value. The principal protein of egg yolk, like that of milk, contains phosphorus, but the fats of milk are phosphorus-free, whereas phosphorized fats (that is, lecithins) are abundant in egg fats. There is an abundance of lactose in milk, whereas the egg contains but a trace of sugar. The fats of eggs are fully comparable with butter fat as a source of vitamin A. The proteins of eggs are of high biologic value. The yolk is poor in vitamin B, but rich in antirachitic properties; it is even curative, but definitely less so than cod liver oil. Eggs vie with milk as a staple food for the production of a vigorous race. It has been shown that an egg a day for a child promotes growth and well-being.

**Classification.** In addition to fresh and refrigerated, eggs are classified in the trade as "rots," "spots," "checks," "ringers," "chickens," "dirty shells," "heated," or "incubated," etc. Eggs are assorted by inspection and candling. Candling consists in holding them before a bright light; the egg is translucent and the movable yolk may clearly be discerned, as well as the air space which is always at the larger end. A practiced eye quickly detects eggs that are not first quality. Rotten eggs are distinguished as "red rots" and "black rots," depending upon the kind of putrefaction. By "spots" are understood eggs that contain opaque spots under the light. These spots usually consist of local growths of mold that have penetrated a crack in the



shell, although they may be due to coccidia, embryos or foreign bodies. "Checked" eggs are those which have slight cracks or nicks in the shell. "Ringers" contain small embryos of about two days' growth, which are flat, disk-like and reddish in appearance. "Chickens" contain embryos of larger growth. Eggs with dirty shells are undesirable more from esthetic than other reasons. The dirt usually consists of hen excrement. A "heated" egg is a shrunken egg, that is, an egg that has been exposed to the summer temperature for several days. Some water is lost by evaporation through the porous shell, the air sac on the end has increased considerably in volume, and in many instances the embryo is partly developed; therefore, heated eggs are also known as incubated eggs. Many of the eggs gathered during the hot months of summer, especially in July and August, belong to this category. These eggs are much less desirable than the spring and fall layings. Eggs are also graded as to size, the very small eggs commanding a lower figure in the market. Further, eggs are classified as strong- or weak-bodied, depending upon how they "stand up" when broken out.

**Bacteria in Eggs.** Eggs as they come from the hen frequently contain bacteria, worms, gravel, blood clots and foreign bodies of various kinds. Practically all eggs contain bacteria, although numerous observers report occasionally that an egg is sterile. As a rule, these observations are based upon planting a small part of the egg. If the entire egg is planted a growth is almost invariably obtained. Thus, in the 18 freshly laid eggs examined every one of them contained bacteria in the yolk; two of them contained *E. coli*. Curiously enough, there are practically always more bacteria in the yolk than in the white; the white contains some bactericidal property, probably similar to that possessed by fresh blood. The bacteria doubtless gain entrance to the egg while in the oviduct. Pernot examined the eggs from over the size of a pea to the perfect egg and found bacteria at every stage. It is well known that the bacteria may also get into an egg through the shell, as it is porous and permeable. When the shell is moist and dirty the chances of growth and mold piercing it are increased. A recently laid egg is covered by a thin layer of protein material called the "bloom." It gives the egg a dull appearance. Although this layer is easily removed by handling, it serves to restrict the entrance of micro-organisms through the shell while it remains intact. Eggs laid in the summer time (July and August) contain many more bacteria than those laid in the spring, fall, and colder months. Summer eggs do not keep as well as winter and spring eggs. Sterile eggs keep better than fertile eggs.

Ordinary methods of cooking eggs do not destroy the bacteria contained therein. Rettger and others (1916) report on an investigation of the possibility of *Salmonella pullorum* in eggs infecting humans. They found that soft boiling, coddling, and frying eggs on one side did not destroy bacteria in the yolks. Other work has shown that boiling eggs until they are very hard and frying on both sides until the yolk is hard will destroy bacteria such as those causing dysentery.

**Eggs and Disease.** Of all standard foods, so far as known, eggs are less liable to convey disease or contain harmful properties than any other single food of animal origin. The literature is singularly free of instances of sickness attributed to eggs. (See salmonellosis, page 207.)

Eggs do not agree with some people, who have an "idiosyncrasy," so that a small quantity will bring on symptoms of allergy. This condition is an instance of

specific hypersensitiveness to egg protein. There are several cases on record in which this hypersensitiveness has been cured by the administration of infinitesimal amounts of egg white, gradually increasing the amount. The entire treatment should extend over a period of months. In this way tolerance may be established in man analogous to the desensitization which may be established by repeated injections of an alien protein into guinea pigs. The treatment is also applicable for other food for which there is a specific idiosyncrasy.

## PLANT FOODS

Plants are the ultimate source of practically all our dietary needs. Carbohydrates and proteins, as well as vitamins, are synthesized in the plant kingdom. In this sense, man lives a parasitic life on the vegetable world. Plants also carry important mineral elements. We do not always take the offerings of the vegetable kingdom directly. A cow eats a liberal plant ration daily during several years to provide the milk and meat for our use.

For purposes of nutrition, plant foods are classified as seeds, roots and tubers, leafy vegetables and vegetable oils; also fruits, berries and nuts. Each class has distinct dietetic qualities.

### THE NUTRITIVE VALUE OF PLANTS

**Seeds.** Seeds are storage organs and can be classed together so far as their food value is concerned. The bulk of seeds consists of starch. The proteins of most seeds are incomplete because they lack some of the amino acids necessary to rebuild human protein. Seeds are also poor in mineral elements, especially calcium, sodium and chlorine. McCollum examined wheat, corn, rice, oats, barley, rye, Kaffir corn, millet seed, flaxseed, pea, and both navy and soy beans. All, with the exception of millet seed, were below the optimum in their content of vitamin A. Seeds are also deficient in vitamin B and in antiscorbutic properties. When seeds alone are used as the sole source of nutriment, it is not possible to secure appreciable growth in young animals.

*Wheat* is the most important seed grain used as food by all western peoples. The chief protein of wheat (gliadin) is superior to that of any other grain. The prominent place of wheat in the diet of mankind is justified by the results of experiments on animals. Wheat, however, is poor in calcium, phosphorus, sodium, chlorine and iodine. The wheat germ contains most of the proteins which are of good quality, is exceptionally rich in vitamin B and contains some vitamin A. The oil of the germ contains vitamin E. In making white flour, the germ and bran are both removed.

*Whole wheat flour* contains about 95 per cent of the kernel, including the germ. *Graham flour* consists of the whole wheat kernel ground to a fine powder between the upper and nether millstones. *Patent flour* is a refined flour made by the roller mill process. *White flour* represents only about 73 per cent of the wheat kernel. Its popularity consists in the fact that it keeps better than whole wheat flour on account of the absence of fats. Furthermore, flour which contains the germ such as whole wheat or graham flour, tends to harbor weevils. Patent wheat flour contains an average of about 11 per cent protein and 72 per cent starch. It is conspicuously lacking in mineral components and deficient in all vitamins. It has become our most



important energy-yielding food. While patent flour is inferior in nutritive value to whole wheat flour, it is a valuable food, but it should be supplemented in the diet to make up for its deficiencies.

*Rice*, next to wheat, is the most important cereal grain in the diet of more than half of the human race. It is used especially in the wetter parts of the world. The practice of polishing rice had its origin in the desire to improve its keeping quality. The demand for white rice and the artificially established liking for white flour and white corn meal are illustrations of the failure of the instinct of man to serve as a safe guide in the selection of food. The esthetic sense is appealed to by products of low biologic values.

**OTHER SELDS.** The proteins of corn have a slightly lower value in nutrition than those of wheat. The oat kernel is comparable to wheat in its dietary properties in nearly all respects. The legume seeds, such as peas and beans, are richer in protein than any of the cereal grains, but nutrition experiments show their protein to be incomplete.

**Leaves.** Edible leaves can be classed together as foodstuffs of similar character. They resemble one another just as do the seeds in other nutritive properties. Leaves are especially rich in just those elements in which the seed is poorest, namely calcium, phosphorus, sodium and chlorine. They are also a source of vitamin A. Thin leaves are more complete foods than thick ones. The thin leaves are cellular structures. The thick leaves contain reserve food material and some, like the cabbage, have been modified to storage organs containing reserve food and comparable to that stored in the endosperm of the seed. The fleshy leaves therefore tend to have in some degree the dietary properties of the seed.

Chief among the leafy vegetables are cabbage, lettuce, spinach, collards, turnip tops, beet tops, Brussels sprouts, endives, dandelion greens, kale and water-cress. Asparagus and string beans have much the same properties as the leafy vegetables.

The leaf is the synthetic laboratory of the plant. It builds up proteins, starch, sugars and fats. The surfaces of the leaf are a mosaic of living cells. They contain all the chemical complexes which are necessary for the nutrition of the animal cells, and are qualitatively complete foods. In general, leaves are analogous to cellular organs of animals, such as liver, pancreas and kidneys, in dietary properties. Leaves are exceptionally rich in minerals, especially calcium and vitamins. They contain vitamins A, B and C, but C is injured when the leaf is cooked. The outer green leaves of head lettuce contain a greater concentration of vitamin A than the inner bleached part. This suggests a relation between chlorophyll and this food factor. The indigestible residue is smooth and nonirritating. The leafy vegetables are excellent supplementary foods.

White celery is succulent, structurally weak and chlorophyll-free. Pathologically it is edematous, rachitic and anemic.

**Tubers.** After the seeds, the tubers of certain plants constitute one of the most important classes of energy-yielding foods. The potato is by far the most important representative in this group in Europe and America, but several other kinds of tubers are widely used as human food in the Orient. The potato and other tubers are classed with the seeds from the standpoint of nutrition, because they consist mainly of reserve material. Potatoes contain vitamin C, and crop failure with famines are part of the history of scurvy.

**Fleshy Roots.** Fleshy roots, such as the sugar beet, sweet potato and carrot, are similar in a general way to the potato, respecting both dietary properties and biological functions. They have a cellular layer at the periphery, and the interior is loaded with reserve foodstuffs. Steenbock and Gross found that carrots and sweet potatoes, both of which contain yellow pigment, are far better sources of vitamin A than are any of the roots which do not have a yellow color, as rutabaga, dasheen, beet, parsnip, potato, mango and sugar beet. Feeding tests have shown that the properties of the beet resemble those of the seed and tuber rather than those of the leaf. The fleshy roots and the potato and the sweet potato have an inorganic content which resembles that of the seed in a general way.

**Fruits and Berries.** The chief uses of fruits in the diet depend upon their salt content, their laxative properties, and their antiscorbutic value. Fruits do not rank high as sources of energy to the body; that is, their caloric values are rather low in comparison with most of the common food products. Fruits are almost without exception devoid of fats and are poor in protein. They are fair sources of mineral salts. Some of them contain carbohydrate, such as the sugars in the orange and the banana. They all have a high percentage of water. The citrus fruits are rich in organic acids.

Most fruits contain vitamin C, especially the citrus fruits—oranges, lemons and grapefruit. The tomato ripened in the field is also rich in it, but those picked green and ripened by time contain very little. Berries contain the same organic acids as are found in the ordinary fruits, which they resemble in dietary properties.

Fruits and vegetables are manipulated and prepared for the market in different ways, some of which interfere with their vitamin content and nutrient value. They are picked green and air ripened; reddened and ripened with ethylene; dried, pasteurized, etc. Methods for removing the residues of arsenical sprays have health implications.

The addition of fruits and vegetables to the diet tends to establish the acid-base equilibrium. They favor elimination and should be used regularly.

**Nuts.** Nuts are the seeds of plants. They are useful but rich, that is, a concentrated food which limits their use in the diet. With the exception of the chestnut, they are rich in proteins and fats but poor in carbohydrates, and are an available source of vitamin B.

The proteins of nuts are similar to those of meat and fish. The protein of coconut contains all the essential amino acids. Since the protein of nuts is fairly high in lysin, it is a valuable supplement to the grain proteins.

Nuts, however, lack a satisfactory balanced mineral and vitamin content, being poor in calcium and vitamins A and C. The homely peanut is relatively rich in basic amino acids in which the cereal proteins are relatively poor. Nuts vary considerably in composition. Chestnuts are starchy; coconuts and walnuts are rich in fat; while almonds, Brazil nuts, butternuts and peanuts are rich in both proteins and fat. Nuts in general, being rich in protein and fat, are comparable with meats as food.

**Vegetable Oils.** Vegetable oils are readily digested and are good sources of energy. Olive oil, cottonseed oil, maize oil, soy bean oil, coconut oil and sesame oil lack vitamin A and are not equivalent to such animal fats as butter and the fat of liver or kidney.



For a further discussion of the nutritive value of plants see McCollum and Simmonds (1925).

### HOW PLANTS MAY INJURE HEALTH

**Poisonous Plants.** Many plants contain a poison, such, for example, as aconitine, strychnine, ricin, abrin, muscarine, and a long list of other substances normally present. According to Chesnut (1902), there are about 500 species of plants in North America which are said to be poisonous. Most of these are rare specimens, and never eaten by man; some are poisonous only during certain seasons of the year; other are poisonous only when introduced parenterally into the human body; still others, such as the poison ivy, are injurious externally only to susceptible individuals, while many of them are known to be poisonous only to domestic animals.

Chesnut estimates that in the United States there are only about 30 species of plants which have been associated with poisoning in man, and furthermore most of such cases must be considered as extremely rare accidents. Instances of such accidents have been recorded by Jordan (1917), who cites the mistaking of the American false hellebore (*Veratum viride*) for the marsh-marigold; the use of the fruit of the Kentucky coffee tree (*Gymnocladus dioica*) in mistake for that of the honey locust; the use of daffodil bulbs for food; the substitution of the mountain laurel (*Kalmia latifolia*) for wintergreen, and the mistaking of the water hemlock (*Cicuta maculata*) for other edible roots. Poisoning from the latter cause is probably more frequent than supposed; in one year, in New Jersey alone, 10 cases, two of which were fatal, occurred. The water hemlock is one of our commonest swamp and brookside plants and one of the most deadly. This is probably the plant by which Socrates met death at the hands of the Athenians. The manuals on poisonous plants cite many other instances of accidental poisoning, due to the substitution, usually by children and the ignorant, of poisonous plants for similar food plants. A good example of this is the eating of castor beans, which are poisonous on account of the ricin they contain. Three or four beans cause violent gastro-intestinal symptoms, five or six are fatal for a child, and 20 for an adult.

There is a great variation in the toxicity of plants, and tropical plants are more often poisonous than those of cooler climates, as is the case with fish, insects, snakes and other animals.

*Mineral substances* in plants rarely cause poisoning. Lead in grass has been shown to be the cause of symptoms of lead poisoning in cows, and plants manured with superphosphates which contain arsenic may absorb enough arsenic to cause sickness. Similarly, there is possibility of poisoning due to the use of insecticidal sprays, washes and powders on vegetables and fruits (see page 453).

*Acids* are of more common occurrence. Prussic acid occurs free in some plants as a glucoside in some others, especially in those of the rose and apple family. The bitter cassava (*Manihot utilissima*), from which ordinary tapioca is derived, contains prussic acid in considerable amount, and cannot be eaten in the fresh state. The prussic acid is dissipated by heat. Cases of poisoning due to this cause are not known.

Oxalic acid is common in many plants, and illustrative of its poisonous quality is the outbreak of so-called "ptomaine poisoning" reported in New York, which was

shown to be due to soup prepared from "Qchav" or "Szchav" leaves, more commonly known as sour grass, a species of sorrel. Two grains of oxalic acid were found in each ounce of the leaves, and four grains in each ounce of the stems of this plant. The soup which was taken contained about 10 grains of oxalic acid per pint. Robb (1919) reports a fatal case of oxalic acid poisoning due to eating dried rhubarb leaves. Marked exhaustion, hemoptysis, early cardiac failure, and greatly delayed coagulation time of the blood were the prominent symptoms observed in this case. The oxalic acid content (as oxalates) of the stalks of rhubarb varies from 1.5 per cent to 40 per cent, but there seems to be no figure available for the amount in the leaves. Many other foods contain oxalic acid, but in harmless amounts.

**OILS.** Some of the common vegetable *oils*, such as the oils of chamomile, cloves, cinnamon, sassafras, etc., may be poisonous in excessive amounts. Chesnut (1902) cites an instance of the death of a child following the ingestion of two nutmegs, while Jordan (1917) calls attention to an outbreak of sickness in Germany in 1911 due to the inclusion of maratti-oil (from the tropical plant *Hydrocarpus*) in a commercial substitute.

**CAROTINEMIA.** As reported by Hess and Myers (1919) a diet rich in carotin, which is the coloring matter contained in carrots, spinach, egg yolk and oranges, may produce a yellow discoloration of the skin, which resembles jaundice, except that the sclera are not involved. Carotin is also present in squash, and pigmentation of the skin has long been observed among vegetarians in Japan, where unusual amounts of this vegetable are used among farmers as a partial substitute for rice. There are no symptoms other than the pigmentation. The carotin and xanthophyll pigments derived from food are the sources of the coloring matters of milk fats and body fats, of egg yolk, of the corpus luteum, nerve cells, and other structures. Carotin (now carotene) is the precursor of vitamin A.

**Parasites.** Certain vegetables, such as lettuce, celery, water cress, radishes, and similar plants, eaten raw, may convey typhoid fever, cholera, dysentery (both amebic and bacillary), the eggs and larvae of animal parasites, and other agents of infections. This occurs from the use of night soil as fertilizer, or from infected water from a foul source. The extensive irrigation of crops of vegetables, generally eaten raw, with river water highly contaminated by raw sewage or the unchlorinated effluents of sewage treatment is a more recent source of danger. Exposure to the sun and desiccation of bacteria on the vegetables during marketing tend to mitigate the danger. All vegetables to be eaten raw should be washed thoroughly beforehand although this cannot be depended upon to remove all the bacteria.

#### POISONING FROM PLANTS

**Rhus Poisoning.** *Rhus* poisoning, also known as *Rhus dermatitis*, or *Dermatitis venenata*, is caused by an irritating resinous substance in the sap of numerous plants. The various plants which may provoke such irritation in susceptible subjects are at least 60 or 70 in number. The most common and best known of this group belong to the genus *Rhus*. *Rhus toxicodendron*, or poison ivy, is distinguished from other suspected creepers of a similar appearance by its possession of three leaflets instead of five. *Rhus diversiloba*, or poison oak, which grows especially in the western part of the United States, is a shrub or small tree. *Rhus venenata*, known as poison



sumac, poison dogwood, and poison elder, is a shrub or small tree, growing in swampy places in the United States and Canada as well as in Japan.

Of the six varieties of the rhus family that grow wild in Japan, *Rhus toxicodendron* and *Rhus vermicifera* are the most injurious. Among the plants which less frequently cause dermatitis are the nettle (*Urtica doica*), the primrose (*Primula obconica*), cowhage (*Macuna pruriens*), smartweed (*Polygonum punctatum*), balm of Gilead (*Podophyllum, Balsanum gileadense*), oleander (*Nerium odorum*), and rue (*Ruta*).

The part of these plants to be feared is the resinous sap. This sticky sap exudes from all parts of an injured plant, and when it comes in contact with the skin causes intense irritation resembling a burn. It frequently begins in the fingers, is acute in character, with swelling, often with vesicles and blebs, the exudate from which is nontoxic. The dermatitis occurs in sharply defined patches, elongated streaks, and other irregular shapes, corresponding with the original area of contact. It does not follow the nerve trunks. It seldom attacks the scalp or the inside of the hands. The original areas of contact are most affected and the parts of the skin to which the poison has been transferred from the original sites of contact are usually less severely affected. McNair (1916) reports that, together with the local lesions, there are a leukocytosis, and constitutional disturbances, such as fever, coated tongue, loss of appetite, constipation, and a trace of albumin in the urine. The attack may subside in from four to six days, depending on the amount of the irritant and the sensitiveness of the skin. Idiosyncrasy plays an important part. Some persons are exquisitely susceptible; others resistant. The resin is not toxic for the lower animals.

The toxic principle in rhus poisoning is not volatile, as was once supposed; in other words, contact is necessary, although not actual contact with the plant itself, for the sap may be carried indirectly by clothing, tools, insects, smoke, etc., to the skin of persons far from the actual neighborhood of the plant, thus explaining those mysterious "recurrent" cases of rhus poisoning. Sap thus carried loses its toxic properties by oxidation, the loss being more rapid at body temperature and moist atmosphere.

Japanese lacquer ware when new has caused a dermatitis in a large number of persons. The sap of the lacquer tree produces typical rhus poisoning. Susceptible individuals may be affected by passing under a lacquer tree, or by simply going by a lacquer-ware shop. This does not mean that the poison is volatile, for in such instances the sap is transferred in some mechanical way.

McNair has shown that smoke from the heated leaves of poison oak causes dermatitis if blown on the wrist. If, however, the smoke is filtered through glass wool, it is no longer irritating, showing that the smoke is only a mechanical carrier of the poison, thus confirming the oft-repeated observation that poisoning may result from exposure to smoke of camp fires, etc. The exact nature of the chemical substance is not known, but it is now clear that it is resinous in nature, and that it is absent from the pollen and plant hairs. The toxic substances in the several plants are identical or very closely related.

Prevention consists in avoiding the plants. In addition, those who are susceptible should exert care in handling articles of clothing, tools, playthings and pets which have been in contact with them. The poisonous plants may be eradicated by spraying with a strong solution of common salt in soapy water or with kerosene. Innumer-

able attempts have been made to immunize against rhus poisoning by ingestion of the leaves, oral administration of the tincture and by hypodermic injection of toxic extracts. None of these measures has proved successful as a preventive.

The dermatitis may sometimes be averted, even after handling these plants, by the free use of an alkaline soap and water, or alcohol, containing a little dissolved sodium hydroxide. The poison is soluble in alcohol and alkalis. Gasoline may also be used. An aqueous solution of sodium bicarbonate is less effective. The washing must be prompt and thorough or else it will only tend to spread the irritating poison.

**Ergotism.** Ergotism is a form of food poisoning brought on by the prolonged use of meal or bread made from grain contaminated with ergot, a parasitic fungus (*Claviceps purpurea*), which is a disease of rye and occasionally of other grains. The fungus grows in the grain as a hard, blackish mass called the sclerotium, the presence of which may be suspected by the color of the meal which is grayer than usual and often shows violet-colored specks. The chief source of the poisoning in man is from rye, in which case the fungus may entirely replace the grain.

The composition of *ergot* is complex and still not completely understood. Several active principles have been extracted. One of these, *ergotoxin*, has a powerful action on the tissues. Ergot also contains several bases, such as *tyramine* and *ergamin* (histamine), which are also found in putrefying meat and are derived from the amino acids, tyrosine, histidine, and leucine by the loss of the carboxyl group. It contains ergosterol, the precursor of vitamin D.

*Chronic poisoning* with ergot may take either of two forms, *gangrenous* or *convulsive*. The gangrene is evidently due to vasomotor constriction and contraction of the unstriated muscle, and usually involves the limbs, especially the fingers and toes, but occasionally the ears and nose. Sometimes the whole arm or leg becomes cold and anesthetic, dark in color, and then dry, hard and shrunken, and falls off with little or no pain and no hemorrhage. In the milder cases there is only skin necrosis. In the convulsive form, the first symptoms are depression, weakness and drowsiness, often headache and giddiness, painful cramps in the limbs and itching of the skin. The spasms are prefaced by muscular pains and cramps and may continue only a few hours or perhaps for days. In severe cases paroxysmal convulsions set in, often epileptiform. This form was often fatal in early times. As a general rule, the gangrenous type prevailed almost exclusively in the epidemics in western Europe, while in eastern Europe the convulsive form was usual.

Ergotism occurred in epidemics from the use of bread containing ergot after poor harvests and especially in wet seasons. The last large epidemic in the United States occurred in New York in 1825. The history of ergot was given by Kobert in 1889. The disease was formerly endemic in Europe, but of late years epidemics have become rare except in Russia. Some of the "plagues" of medieval Europe may have been due to ergot poisoning. Hirsch reported some 28 outbreaks in the nineteenth century.

**Lathyrism.** Lathyrism or vetch poisoning is a rather rare condition met with in some parts of Europe, notably Austria and Italy, in northern Africa, and in India. It is associated with wretched conditions of living. The vetch seed is ground in the form of meal and used as a partial substitute for wheat. The seed is popularly known as chick-pea. The vetch seeds are obtained chiefly from *Lathyrus sativus* and *Lathyrus cicera*. The eating of bread prepared from meal containing the seeds of the



lathyrus is followed by sudden and severe pains in the lumbar region, girdle sensation, spastic motor paralysis of the lower extremities, tremor and fever. The nature of the poison is not known, but it is probably of the nature of a toxalbumose, of which ricin and abrin, the poisons of the castor bean and the jequirity bean, respectively, are well-known examples.

**Favism.** Favism (*fava*, bean) is the name applied to a disease which has been reported in Italy. It is attributed to the use of beans as food, or even just smelling the blossoms of the bean plant. It is said to occur only where beans are cultivated on a large scale, and then usually only during the spring of the year. Of 1,211 cases which were studied by Fermi in Sardinia, 752 were ascribed to ingestion of the beans, and 459 to inhalation of the odor or pollen of the bean plants. The onset of symptoms occurs a day or so after ingestion or from two to six hours following inhalation. It is distinguished by acute, febrile hemolytic anemia with jaundice and hemoglobinuria, but there may also be abdominal pain, nausea, vomiting and diarrhea.

**Mushroom Poisoning.** The ill effects from eating mushrooms are usually due to mistaking the poisonous for the edible species, and in America this is usually done by children, immigrants or the ignorant.

The number of species of poisonous mushrooms which are capable of causing death is not very great, perhaps 20 or 30. *Amanita* and *volvaria* are the most poisonous genera, and are the ones usually involved in the fatal accidents.

Ford (1906) estimates that from 12 to 15 deaths occur annually in the United States from *amanita* poisoning. In September, 1911, in the vicinity of New York, following heavy rains, 22 deaths were reported.

*Amanita phalloides* and *Amanita muscaria* are exceedingly poisonous, dangerous and seductive species, responsible for most of the deaths from toadstool eating. *Amanita phalloides*, because of its white color, is mistaken for the common mushroom, *Agaricus campestris*. *Agaricus campestris* does not grow in the woods, neither has it white gills, nor white spores, nor a volva at the base of the stem. No dependence, however, should be placed upon color, size, shape or general appearance. It often requires a trained mycologist to distinguish one species from another.

The first historic instance of mushroom poisoning occurred in the family of the Greek poet, Euripides, who lost, in one day, wife, daughter and two sons. Among others whose lives have been sacrificed through ignorance may be mentioned Pope Clement VII, the Emperor Jovia, Emperor Charles VI, Berronill of Naples, the widow of Tsar Alexis, and the Princess of Conti. Poisonous fungi have figured prominently in many of the accidental and craftily malicious tragedies of history.

Poisonous mushrooms contain at least four classes of poison: (1) a "toxin" represented by amanitotoxin; (2) muscarin, an alkaloidal-like substance, resembling pilocarpine; (3) a hemolytic poison; and (4) a number of poisons more or less ill defined, such as the Pilztoxin of Harmsen. These poisons do not all occur in any one species, but are found singly and in various combinations in the different genera and species. Ford (1923) classifies mycetismus, or mushroom poisoning (1) gastro-intestinal, (2) choleric form, (3) nervous form, (4) hemolytic and (5) cerebral form.

*Amanita phalloides*, the "white or deadly amanita," is the cause of the greatest number of cases of mushroom poisoning, if we include in this group *A. verna*, *A.*

*bulbosa*, *A. alba*, *A. virescens*, *A. mappa*, and many other species known by various names in different localities. Fatal poisoning takes place when the fungi are eaten raw or cooked. Two or three deadly amanitas are sufficient to cause profound illness with fatal outcome in an adult. Plowright reports the death of a child of 12 years from eating a third of the pileus of a small raw plant.

In 1891, Kobert isolated from *Amanita phalloides* a substance having a powerful hemolytic action which he called *phallin*. For some time it was believed that phallin was the essential poison of *Amanita phalloides*, but Ford (1906) showed that there is another substance present which is much more toxic, and to which most of the symptoms can probably be traced. This is supported by the fact that boiling *Amanita phalloides* destroys its hemolytic power, but fails to neutralize its toxic action. This substance Ford has called "amanitotoxin" and states that it has no hemolytic action, but rather produces hemorrhage and causes necrosis and fatty degeneration of the parenchymatous organs. He also succeeded in producing an antihemolysin which completely neutralizes the blood-laking properties of phallin. Clark and others (1915) found that in cases of *Amanita phalloides* poisoning, the pathological lesions consist chiefly of central necrosis of the liver, epithelial necrosis of the kidney, acute enteritis and colitis, the kidneys being the seat of the most marked changes. These investigators conclude that the nervous and mental changes observed are probably uremic in character, and not due to some peculiar "neurotoxin."

The symptoms of poisoning by *Amanita phalloides* usually do not develop for from 6 to 15 hours after ingestion, the onset being marked by sudden, severe abdominal pain, intense thirst, nausea, retching, vomiting and profuse watery evacuations, sometimes containing blood and mucus. A state of collapse may soon develop. There is usually a rapid loss of strength and flesh, and the patient develops a peculiar yellow color. The pupils are usually contracted; the breath is quite fetid and the mucous membranes dry and glazed, and there may be bleeding from the gums. Visual disturbances leading to confusion, delirium and convulsions may develop, but convulsions are usually due to a mixed intoxication, which in turn is due to *Amanita muscaria* being mixed with *Amanita phalloides*. After three or four days in children, and usually six or eight in adults, the patients sink into a profound coma from which they do not often awake. Ford (1906) states that the case fatality rate of *Amanita phalloides* poisoning is from 60 to 100 per cent. The danger is much less in the case of *Amanita muscaria*.

Muscarine is the active poisonous principle of *Amanita muscaria* (*Agaricus muscarius*, "fly" amanita). Muscarine ( $(\text{CH}_3)_3\text{NOH} \cdot \text{CH}_2\text{OH}$ ) is a syrupy, alkaloidal-like substance obtained in crystallizable form as a hydrochloride. It was first isolated by Schmiedeberg and Koppe in 1869. Chemically it evidently is an ammonia substitution compound and is classed with the ammonia bases. It may be prepared synthetically by the oxidation of chlorine.

The physiological action of muscarine resembles pilocarpine very closely. It stimulates the myoneural junctions between the nerves and epithelial cells. Atropine is an almost perfect physiological antidote for muscarine, paralyzing the myoneural junctions, and is used with more or less success in mushroom poisoning.

The symptoms of muscarine poisoning come on quickly, often within 15 minutes after eating the mushroom (*Amanita muscaria*). They consist of salivation exces-



sive perspiration, a flow of tears, nausea, retching and vomiting, pain in the abdomen, and violent movement of the intestines, causing profuse watery evacuations. The pulse is sometimes quickened, sometimes very slow and irregular. The pupil is contracted, respiration often quickened, and dyspneic. Dizziness and confusion of ideas are often complained of, but mental symptoms are not so conspicuous as those from the peripheral organs. Mental symptoms, such as hallucinations, delirium and convulsions are attributed to the Pilztoxin of Harmsen. Eventually the respiration becomes slower, great muscular weakness supervenes, but consciousness remains more or less clear until the breathing ceases.

The peasants of the Caucasus prepare an intoxicating beverage from *A. muscaria* which produces wildly riotous drunkenness. Death from muscarine orgies is not uncommon in this part of Russia. Similar species in Northeastern Asia are also used as an intoxicant. The poison is excreted in the urine which is sometimes later consumed for its intoxicating effect. It is probable that a sort of tolerance to muscarine is developed among the habitual users of the muscaria decoction.

The alkaloid is soluble in water and poisoning may be prevented by soaking the mushrooms in water slightly acidulated with vinegar before they are cooked.

**Potato Poisoning.** Outbreaks of poisoning attributed to potatoes have occurred among troops. In 1895, Schmiedeberg reported outbreaks involving 357, 90, 125 and 101 men, respectively, and in 1899, Pfuhl recorded an outbreak involving 56 soldiers. The trouble was attributed to potatoes, sometimes new, sometimes old sprouting ones, and sometimes potato salad.

The onset of symptoms occurs usually only a few hours after eating the potatoes. Symptoms reported have been headache, abdominal pains, nausea, vomiting, diarrhea, prostration, dizziness, drowsiness and slight delirium. Fever has usually been absent. In some cases, dilatation of the pupils is reported. The symptoms only rarely become threatening and practically all the victims recover rapidly.

These cases were long regarded as solanin poisoning, but it is now plain that this does not account for outbreaks, some of which at least are bacterial in origin.

*Solanin* ( $C_{42}H_{75}O_{15}N_4$ ) is a glucosidal alkaloid closely resembling the saponins in reaction, and found in many species of *Solanum*, such as *S. nigrum* (black nightshade), *S. dulcamara* (bittersweet), and *S. tuberosum* (potato). The solanin content is highest in the potato peel, decreasing toward the center of the potato. It occurs chiefly in immature, sprouting or diseased potato parts which ordinarily are discarded before cooking.

Toxicologic tests on man have demonstrated that 0.2 gm. of isolated solanin may provoke untoward symptoms. Seldom would that amount occur in the quantity of potatoes which an adult might consume in the course of a day.

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# 24

## FOOD ESTABLISHMENT SANITATION

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The construction and operation of establishments in which foods are processed or in which they are prepared and served influence the safety and quality of the foods handled therein. Frequently, design and construction details which favor the protection of the health of workers and of the food consuming public and facilitate plant sanitation may be included not for those reasons but because they cut maintenance costs. The two go hand in hand. Even after foods are packaged, mishandling during shipping and storage may affect the sanitary quality as well as the nutritive value of such foods. For example, unfavorable conditions with respect to moisture and temperature may cause unwanted fermentation, and rat feces or urine may contaminate food. Manufacturers and processors of foods have become conscious of this to the extent of employing sanitarians to supervise their plant housekeeping. Good plant construction simplifies this function.

**Types of Food Establishments.** There are many types of establishments in this category; for instance, canneries, frozen food packing plants, bottling plants, breweries, flour mills, bakeries, plants producing edible fats and oils, milk and milk products plants, candy factories, syrup plants, sugar refineries, abattoirs, meat packing plants, food locker plants, cold storage and other food warehouses, as well as retail food markets and restaurants. The word "restaurants" is used here in the broad sense to include all establishments in which food or drinks are served to the general public. The special problems in the health field vary with type of establishment but common basic principles of control are quite generally applicable.

**Location.** Still speaking generally, the location of the plant is of fundamental importance from the standpoint of health as well as for economic reasons. A good potable water supply is the life blood of most food establishments and should be a primary consideration in the selection of the site. The chemical composition of the water also is important. Chlorination may be necessary and softening often is essential to maintaining clean equipment and a good product. Of equal importance are drainage of the site; sewage, waste and garbage disposal facilities; and assurance that gaseous wastes may be discharged into the air without health hazard or odor nuisance. The classification of natural waters into which wastes or effluents may be discharged has an important bearing upon the cost of waste treatment and the possibilities for the ultimate disposal of liquid wastes and, therefore, is a factor in selecting the site for a food plant. Interference from nearby industrial plants as through smoke, dust- or odor-laden air also should be considered. Other ordinary considerations in the selection of a site for any plant such as space for expansion,



shipping facilities, and suitability for the purpose may affect sanitation indirectly if not directly.

**Danger of Floods.** An item that may be easily overlooked in the selection of a site for a food processing or storage plant is the danger of flooding. Irreparable damage may be done to foods by flooding of a plant with polluted river water. The salvaging of foods from flooded plants has created serious problems for health officials. In one instance a large lot of chicle worth thousands of dollars which was drenched with sewage polluted river water was required to be held for months until freedom from coliform organisms was demonstrated and the chicle then was assumed to be free of pathogens and released for use.

**Water Supply.** Where a municipal water supply is not available at reasonable cost, development of an adequate supply of water satisfactory for various uses is of great importance. The fact must be recognized that our ordinary surface and ground water supplies are not just  $H_2O$  but a conglomeration of added chemicals, in small concentrations as a rule, but nevertheless capable of entering into reaction with foods, detergents or other substances. Filtration or chlorination or both may be necessary to make the water safe for human consumption. Generally it pays to soften and condition the boiler water supply to prevent encrustation. Softening of the water for cleaning or other purposes also may result in economies, improved food quality and improved operations. Iron removal may be necessary. Making the water immediately available in ample quantity at the various points where it may be needed throughout the plant is essential to efficient operation. Too frequently jobs such as washing containers are done ineffectively because of faulty design of pipe lines within the plant.

**Waste Disposal.** The disposal of liquid wastes may be or become a serious problem for plants discharging large volumes of such wastes. The advice of a competent consulting sanitary engineer should be sought in connection with special problems. The construction and operation of special plant waste treatment facilities usually is costly. The disposal of effluents from treatment plants also may become a problem. A southern New Jersey freezing plant with liquid waste amounting to 10,000,000 gallons on peak packing days reports that it is disposing of this waste economically by spraying it at a rate equivalent to 50 inches of precipitation per week in a forest. Similar nearby cultivated land would not absorb a small fraction of this waste.

**Sewage.** The discharges from the water closets and urinals should be handled in city sewers wherever possible. When sewage must be disposed of on the premises it should be handled separately from the food wastes and other drainage in order to minimize the quantity of waste that may contain human pathogens and to utilize for this purpose well known sewage disposal methods as by septic tank and cesspool or subsurface drainage which are not likely to be applicable to the bulk of the liquid waste.

**Solid Wastes.** Solid wastes from food plants vary tremendously in character and quantity. In small plants ordinary garbage disposal facilities may be utilized. The storage of garbage cans in specially designed cold rooms has been utilized to advantage to control fly breeding and prevent odors. Special wastes may be put to special uses. For instance, some sugar plants utilize the waste sugar cane after extracting the juice to operate the boilers and manufacture alcohol and ether from the waste

molasses, a mixture of which is used to operate sugar farm tractors and automobiles. The problem of disposal of solid wastes is one of the many that must be solved satisfactorily for smooth plant operation without nuisance.

**Height of Buildings.** In new structures the trend appears to be toward single story buildings with high ceilings and relatively few partitions. Such buildings generally lend themselves readily to the maintenance of good sanitation. However, multistory buildings often are necessary and there is no reason why such structures cannot be so built as to make it easy to maintain good sanitary conditions therein.

**Plant Layout.** The factors that ordinarily affect plant layout, such as the even flow of materials to prevent the crossing of lines of movement, generally favor sanitary maintenance. In estimating the required floor space for food processing machines it is especially important to allow sufficient room around each unit to permit the easy removal of every part for cleaning and servicing as well as to permit cleaning of the outer surfaces of the machine. For instance in well planned milk pasteurizing plants it is likely that not more than one quarter of the usable floor space will be covered by equipment. Required headroom depends somewhat on the type of operation and needed heads for gravity flow of the product through equipment. Frequently, workrooms in plants that are easy to operate and maintain have ceiling heights between 15 and 20 feet.

**Materials.** The materials used for constructing the building are important from the standpoint of sanitation as well as from the standpoints of appearance, fire resistance and durability. Well-mixed concrete with smoothly trowelled surfaces is satisfactory for most purposes. Concrete blocks and cinder blocks present rather rough wall surfaces that are unsatisfactory in places subject to splashing with food. The growth of bacteria and molds on walls may become a problem. Smooth glazed tile walls usually are satisfactory and are easily maintained. The use of hollow tile for inner partition walls in warehouses has presented a problem from the standpoint of rodent control. Many tiles have been found to be broken or nicked sufficiently to permit rats to enter and nest in the hollow spaces. In general surfaces should be smooth, hard and easily cleanable.

**Floors.** Hard, wear-resistant floor brick or tile can be used to advantage for floors frequently wet and which are subject to wear as from rolling cans or barrels or trucking products over them. The inclusion of a steel grating, such as subway grating, in the surface of a concrete floor also serves to provide a wear-resistant surface. Another possibility is to incorporate a fine flint aggregate into the surface layer of concrete in floors. Terrazzo floors are subject to cracking and to attack by weak acids in wastes.

**Floor Drains.** Where floor drains are needed they should be placed close enough, say not more than 20 feet on centers, to avoid great differences in elevation between high and low points. Slopes of one-fourth inch per foot are sufficient and with careful finishing of the surface this may be reduced three sixteenths of an inch. Floor drains should be trapped and connected in accordance with the Standard Plumbing Code.

**Lighting.** Whether light is provided in working areas by means of windows or by artificial means or both is not likely to have a direct bearing on sanitation or health of personnel, providing good light is available at all times. In northern climates it is important that the artificial lighting be adequate as it is likely to be used a large percentage of the working hours. Considerations of morale, first cost and



economy of operation may determine how much natural lighting to provide. The important consideration is to direct natural light with alternate artificial light so as to prevent glare and at the same time to provide all points where food handling or cleaning operations are carried on with adequate light for the purpose. It is almost certain that a surface which the worker cannot see easily during the cleaning process will not be well cleaned.

An arbitrary standard suggested for public eating and drinking establishments by the United States Public Health Service Code is 10 foot-candles of light as measured by light meter on all working surfaces and places where utensils are washed and four foot-candles at 30 inches off the floor in storage areas. The basic criterion is that persons charged with the important duties of preparing and handling food for human consumption or of cleaning and disinfecting the equipment or containers with which it comes in contact shall have sufficient fixed light to clearly see that this work is done well and that there are no visible contaminants in the food. Dependence should not be placed upon the routine use of electric lights on leads which have to be carried from one point to another as the workers may not find it convenient to use them.

**Ventilation.** Ventilation is as important, if not more so, in the food plant as in many other types of work rooms. Excessive humidity and the presence of foreign odors are likely to be damaging to the flavors and consistencies of foods. Dust also may be harmful. Ventilation by air inlet and vent flue will do for some operations. In specific locations or over cooking operations, hoods and exhaust fans are necessary. For a number of operations in food plants in which control of flavor, texture or moisture content is important air conditioning is essential.

**Toilet Facilities.** The provision of adequate toilet facilities for employees generally is required under labor laws. Much effort has been directed toward requiring vestibules and self closing doors between toilet rooms and rooms in which food is handled. The basis for this is that flies may carry pathogens from fecal discharges to foods and that without this protection foul odors are more likely to reach foods. This is more of an esthetic than a health problem. Vestibules frequently do not serve the purpose for which they were intended. It is good practice to locate toilet rooms next to locker rooms. It is important that handwashing facilities be provided where they are convenient for workers after using the toilets, as well as in locations where food or sterile containers are handled. It is desirable that basins be installed with running hot and cold water and that soap and single service towels be provided. Many sanitary codes require that such facilities be provided. The posting of signs stating that workers are required to wash their hands after visiting the toilet and before returning to work is required in some health jurisdictions. Attractive pictures of hand washing may be a more pleasant reminder. This is one of many details of the personal hygiene problem which can best be handled by education of food handlers in this important subject.

**Disease Carriers and Cases.** The body discharges of workers in food handling establishments constitute a source of pathogenic bacteria necessary for the spread of human diseases. Fortunately, most workers carry pathogens in such discharges only sporadically and many of the bacteria in the spray from coughs and sneezes and those transferred by soiled hands do not fall on fertile ground. In other words instead of gaining access to bland moist foods they may be transferred to foods that

are too dry to support bacterial life for long periods or otherwise unfavorable or they may enter foods which later are subjected to heat treatment sufficient to destroy such organisms. Chronic carriers of diseases, such as typhoid fever, when they work at food handling frequently cause record outbreaks. The public health program of following up cases of disease likely to result in carrier status, thus locating carriers who then can be prohibited from handling foods and kept under surveillance, has been fruitful in decreasing the number of recorded food-borne outbreaks of such diseases. Nevertheless, every practical safeguard should be taken to see that carriers do not work in food plants.

**Medical Examinations.** Attempts at controlling the spread of diseases through routine medical examinations of food handlers have been decidedly unfruitful. In fact they tend to give a false sense of security. Some diseases develop very rapidly. Physical examinations cannot be made frequently enough nor, in quantity, thoroughly enough to offer real protection. Perhaps the best that can be done is to encourage workers to report illnesses no matter how minor, to provide sick leave or temporary employment that does not involve food handling for such workers and also for those with suppurating wounds on exposed parts of the body.

**Food Handler Training.** Wherever workers in food plants handle foods to be served without further cooking, health officials are justified in requiring training in personal hygiene. Much has been done directly by health departments in establishing such training courses. Such departments are in a good position to know what should be taught and have personnel who know the subject but seldom can combine this with good educational methods. Furthermore they are not usually well enough staffed to continue offering such courses indefinitely. Team work between health departments and departments of education may lead to putting food handler training on a sound basis from the standpoints of quality and sustained effort.

**Rodent Control.** For food handling plants in general, the design of the building and the building materials should be such as to build rats out. Such things as false ceilings, boxed staircases, enclosed hollow wall spaces of nonrodent-proof materials and improperly boxed counterweights should be avoided. Access of rats should be barred to places where they can secure food or drink.

**Roaches.** Similarly, life in the food plant can be made unattractive to roaches by eliminating harborages, as by avoiding loose mouldings, sealing electric fixtures and conduits, and making it difficult for roaches to reach food and water.

**Flies.** The answer to the control of insects such as flies is not simply screening. Screens keep flies in as well as out and with the continuous moving of goods into and out of the building many gain access to the building notwithstanding effective screening. The incorporation here and there of well-placed panels of electric screening frequently is effective. Flytraps also may be used with good effect. The use on walls and ceilings of contact poisons such as DDT or chlordane may be satisfactory, at least until resistant strains of flies develop in rooms that may be treated at times when no food or containers or equipment with which food may come in contact are exposed. Caution must be observed to avoid the use of contact poisons in places where they may scale off or drop into foods, or food containers or equipment. The routine use of space sprays is not indicated. However, they may be used under controlled conditions. Some plants resort to directing the air currents from powerful fans against much used doorways to keep flies out. The provision of entrances only



through refrigerated vestibules generally is impracticable but may impose an effective barrier against flies. Electric screens and flytraps may be used economically and effectively.

**Infestations.** For special types of food plants frequent fumigation may be necessary to control such insects as weevils or beetles or their larvae. In some instances it may be advisable to install and use fumigation chambers through which all products entering or leaving the plant must pass. Fumigation is a special problem in flour mills where such insects as the confused flour beetle may cause considerable damage to the product.

**Fumigation.** The infestation of foods with insects or their larvae is repulsive to the consumer and the tendency on his part is to destroy foods so contaminated. However, there is no convincing evidence at the present time that specific diseases may be transmitted in this way. In instances where supplies of food have been limited, as with combat forces, attempts have been made to remove insects by sieving flour or to use the flour including the insects, larvae and eggs without apparent ill effects. The only satisfactory procedure commercially is to control such insects by fumigation at the manufacturing plant followed by packaging in well-sealed units.

**Fumigants.** Among the fumigants used in gaseous form are methyl bromide, ethylene dichloride mixed with carbon tetrachloride, chloropicrin and hydrocyanic acid. Methyl bromide is valued because it penetrates well, is noninflammable, non-explosive and does not injure equipment or most foods. It is effective but relatively slow in action so must be securely confined and cannot be used in loosely constructed buildings.

*Ethylene dichloride* ordinarily is mixed with 25 per cent of carbon tetrachloride to cut the fire hazard. The mixture evaporates to form a penetrating heavy gas which sinks to the bottom of confined spaces. Like other fumigants it must be used with caution but is slightly less toxic to man and insects than hydrocyanic acid gas and chloropicrin.

*Nitrotrichloromethane* or *chloropicrin* is toxic to insects in all stages. It tends to cling to fumigated objects requiring thorough airing after fumigation. Explosion or fire hazard is not a problem. It is quite irritating, especially to the eyes.

*Hydrocyanic acid gas* is most effective. It works rapidly and without damage to most foods. In the concentrations used it does not create a fire hazard. Great care must be exercised in its use because it is a deadly poison to humans.

**Provisions for Fumigation.** In designing a new plant the need for the control of infestations should be recognized depending upon the foods to be handled and provisions should be made for methodical control by fumigation or otherwise. Failure to build so as to make control simple and the application of spasmodic efforts to clean up when conditions become unbearable is not only unscientific but unbusiness-like.

**Air Conditioning.** The control of temperature or humidity or both during processing is important in some food plant operations. With modern air conditioning this can be done according to need. The removal of particulate matter or gases from the air circulated through the plant or used in processing may in some instances be a necessity. Savings in waste and added returns resulting from the production of consistently high class products generally will cover the cost.

**Instrumentation.** Instrumentation throughout the plant may not have a direct bearing on health but should help improve the keeping quality and nutritive value of the product which is an indirect benefit to health. Such instrumentation may include automatic temperature and pressure controls with chart records and automatic timing of processes. Such control is invaluable in food processing. From the standpoint of public health this is especially true of operations involving pasteurization or sterilization. It may be carried further to automatic sorting operations and color control.

**Control Laboratory.** The product control laboratory is an essential element in maintaining a uniformly sound, tasty, good looking and nutritious food product. This laboratory also should be utilized to check the sanitary quality of such foods. Surprising evidence has been obtained in a number of instances of the part played by bacteria of devious kinds in changing the initial product or by-products and in making it difficult to maintain good quality. Good laboratory work can do much toward resolving operational difficulties and at the same time make the product safe.

**Storage.** Adequate facilities must be provided for the storage of packaged products pending shipment. For unrefrigerated storage, systematic stacking of the product in such manner as to avoid the creation of rat harborages is necessary. Where floors are damp, metal frames may be required to keep the first layer of cartons off the floor. Some products, such as evaporated milk, require inversion at monthly intervals, but even these should be stacked carefully to avoid forming nesting places for rats or, if this is not done, the interval between inversions should be made less than 25 days which is the average gestation period for rats. For the storage of products in bulk or in cloth or paper sacks rodent control is especially important. In addition to many other skills the plant sanitarian should be trained to recognize rat runways and rat harborages. He can do much to facilitate rodent control in his periodic inspections of the plant, including storage rooms.

**Cold Storage.** Where cold storage of products is necessary, attention should be given to the construction of floors, walls and ceilings to provide adequate durable insulation. Duplicate refrigeration units are desirable with a standby power source, if possible. Either good circulation of air should be established to maintain a uniform temperature in various parts of the cold storage room or the temperature distribution should be studied and various foods should be so placed as to be in the most favorable temperature zone. The ripening or curing in cold storage of products such as Cheddar cheese has been shown to proceed much more rapidly at 60° F than at 40° F. Since pathogens, if present, tend to die off more rapidly with speedier ripening this is one instance favoring a higher storage temperature.

The control of cold storage plants either operated by a food plant or as a separate entity in the food marketing program is considered necessary in many states for the protection of consumers. Direct health hazards are believed to be unlikely. However, with gross mismanagement, which would be possible without control, problems could arise resulting in food poisoning or the culturing in food of chance pathogens. Present control consists largely of licensing operators, requiring the numbering and dating of individual lots of food, regulation of storage temperatures, the keeping of records, periodical reporting, and restrictions upon the length of time certain foods may be held in storage.



**Frozen Food Locker Plants.** Since the introduction of the process of quick-freezing foods for storage, there has been a rather extensive development of frozen food locker plants, especially in rural communities. There appears to be a tendency to start such plants on limited capital and in some instances to develop them by adding slaughtering and food processing operations beyond the limitations of the original plant or site resulting in insanitary conditions. Furthermore, the original insulation of the cold storage rooms and capacity of the refrigeration plant are likely to be inadequate. As the result of the study of this problem the Committee on Sanitary Engineering and Environment of the National Research Council made the following recommendations:

1. It appears to be most important that operators who proposed to build locker plants be required to have plans drawn up under the supervision of a competent engineer and to submit them to and secure the approval of the state health authority before any construction work is commenced.

2. To insure low heat infiltration and thus encourage the maintenance of required low temperatures, special attention should be given to the construction of the floors, walls and ceilings of cold rooms and of the conductances of materials used in building them.

3. Separate compressors of the same make should be provided for the chill room, and for the sharp-freeze and storage rooms. Each of these compressors should have sufficient capacity to carry the whole cooling load and should be so installed that it can readily be used for either service.

4. Standby electric service should be provided wherever possible.

5. Locker plant operators should consider future requirements for services such as operating slaughter houses, meat processing plants, food processing plants, kitchens and bakeries in conjunction with their locker plants.

6. Locker plant regulations should be sufficient to insure health and sanitation without standing in the way of individual initiative and progress.

**Equipment.** Too much of the equipment in the food field has been designed and built by well intentioned engineers with extensive experience in building for mechanical perfection but little if any knowledge of public health, sanitation or food quality control. In fact, frequently, little attention has been given to the effectiveness with which the equipment performs the function for which it is intended. Engineers in the public health field have been insisting more and more that primary consideration be given to performing public health functions and to construction that makes cleaning easy. Beyond this, maintenance of quality of the product becomes the next important item.

**3-A Standards.** Realizing that the setting of standards for milk plant equipment by each local health department would result in confusion and require expensive custom-made equipment and that health officials, suppliers and users of equipment had identical interests, the International Association of Milk and Food Sanitarians, the United States Public Health Service and a Dairy Industry Committee are co-operating in a program for setting standards known as 3-A or three agency standards for various pieces of milk plant equipment. This program is well under way and a number of standards have been established to the apparent satisfaction of all concerned.

**N.S.F. Standards.** More recently the National Sanitation Foundation has in-

augurated a program in which a joint committee comprised of representatives of all the leading public health associations in the United States, working with task committees of various industries in the food equipment field will establish what are known as N.S.F. standards for food equipment in those fields. It is the intention to permit the use of an identifying seal of approval on equipment that has been tested and found to meet the established standards. The State and Territorial Health Officers Association acted at their meeting in 1950 to encourage the creation of such standards by the National Sanitation Foundation. Work now is in progress for establishing standards for soda fountain and luncheonette equipment, for food service equipment, and for spray-type dishwashing machines.

**Official Control of Plants.** The regular inspection of milk pasteurizing plants by local health departments is an established procedure. The public health need for official control of retail food stores and of restaurants is recognized and many local health departments perform this function. The amount of work to be done is tremendous. Progressive business men realize that it is to their interest to maintain good sanitary standards. The most successful programs in this field are being carried on primarily by industry with the cooperation of health and other officials.

**Restaurants.** Popular demand for the inspection by health officials of public eating and drinking establishments stems from occasional observations by patrons of revolting conditions surrounding the preparation and serving of food, in addition to attacks of food poisoning they experience. Regardless of relative health importance, the public frequently insist upon official control. Enforcement procedures that have been tried include alphabetical grading, numerical scoring, awarding approval and the issuance of revocable permits or licenses. Any of these systems can be made to work but none are self-enforceable and all require constant effort on the part of operators and enforcement officials.

The same general principles of sanitation apply to restaurants as have been discussed for food plants generally. Primary considerations are safe water and food supplies. Only pasteurized milk and milk products, including cheese, should be served. Cases of undulant fever among persons who always drink pasteurized milk at home have been traced to the unwitting consumption of infected raw milk products at unsupervised wayside eating establishments. Pork should be thoroughly cooked. Other foods, such as oysters, should be secured from approved sources. Adequate refrigeration is essential especially for cooked meats, custard filled pastries, and similar foods in which toxin producing bacteria may grow. Such foods have been responsible for many reported outbreaks of food poisoning. The training of all food handlers in hygienic methods of performing their daily tasks generally is recognized as of equal importance. An Ordinance and Code Regulating Eating and Drinking Establishments has been recommended by the United States Public Health Service (1943). This contains explanations of the public health reasons for various requirements, suggested enforcement procedures and an inspection form. Those who do not favor alphabetical grading may use the alternate provision for enforcement by permit revocation.

**Washing and Sanitizing Dishes.** Serving drinks in soiled glasses and food in soiled dishes or supplying food encrusted silverware is disgusting if not a menace to health. The finding of wash water with a standard plate count of 3,000,000 per ml. in a single-tank dishwashing machine in a busy city restaurant pointed out the



possibilities. This does not represent average conditions but it occurred in a popular and supposedly well operated restaurant located on the main street of a large city. The potential hazard is apparent when it is taken into consideration that this wash water was maintained at a favorable incubating temperature, became a good medium for bacterial growth through constant additions, from soiled dishes, of residues of food including milk and gravy, became a haven for organisms from the mouths of hundreds of patrons, was not completely emptied between meals providing long incubation periods, and that the final rinse water was applied for perhaps 10 seconds at a temperature of about 140° F and did not strike all portions of the dishes due to the shielding effect of the wooden dish racks. A study of mechanical dishwashing by Mallmann and others (1947) served to point out the importance of maintaining adequate temperatures and pressures, fixing time intervals and securing good spray patterns in mechanical dishwashing. This was implemented by a report by the National Research Council (1950) giving users, especially the armed forces and hospitals, a basis for buying and installing machines that can be operated effectively.

**Single Service.** Expendable paper cups and paper or wooden forks and spoons are available in a number of forms. Bacteriological examinations of packaged cups have shown them to be quite free of bacteria in general and there is no evidence that pathogens may be found. With normal current methods of manufacture and handling their use does not present a public health problem. Where adequate facilities for washing and sanitizing utensils cannot be provided as, for example, at small concessions at fairs, the use of single service containers is essential. For many other uses paper is acceptable and economical. There have been instances of abuses such as the re-use of cups used for serving water. Generally, single service paper containers may be used with confidence as to safety and sanitation.

**Conclusion.** Food is used so generally, affects health so directly, and is subjected to so much handling and holding in storage in its passage from farm to consumer that the public has a vital interest in the sanitation of the plants and processes through which it passes. Fortunately, factors that favor maintaining good quality, which is something the consumer can judge for himself, also favor the protection of the public health and maintenance of good sanitary practices. Self-inspection by industry is an important adjunct. Effective official control at all stages of handling is impractical and must necessarily be limited to certain phases of food handling which are commonly acknowledged to be of more direct public health importance.

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# Section Five

## ENVIRONMENTAL MEDICINE

ANNA M. BAETJER, Sc.D.

### 25

#### TEMPERATURE

##### HIGH TEMPERATURE

**Mechanisms of Heat Loss.** The ability of the body to maintain an almost constant internal temperature while exposed to a wide range of external temperatures is due to its remarkable power of physiological adjustment. The human body is constantly producing heat as a result of metabolic processes within the cells. In order to maintain heat balance, a compensable amount of heat must be lost continuously. Excessive heat loss to cold environments or failure to lose heat in hot environments is disastrous to life. Only by adjusting the heat loss and heat production in relation to environmental conditions can the body survive.

The principal route of heat loss from the body is through the skin; small amounts of heat are lost also through the excreta and the expired air. Heat may be lost from the surface of the body by three methods: (1) conduction-convection, (2) radiation, and (3) evaporation. The environmental factors which determine the rate of heat loss through the skin are: the temperature of the air, the temperature of surrounding objects, the relative humidity, and the air movement.

When the air temperature is lower than the skin temperature, heat is lost from the body by conduction. Heat loss by conduction \* involves the direct transfer of heat to the air in contact with the skin or clothing. When the air in contact with the body becomes heated, it becomes less dense and rises. It is replaced by cooler air which in turn becomes heated. This motion of the air which results from differences in density is known as convection.† The rate of heat loss by conduction-convection depends on the difference between the temperature of the body surface and that of the air in contact with the surface—the greater the difference, the greater the heat loss. The skin temperature is normally between 31° and 32° C. Any adjustment which raises the temperature of the skin will increase the heat loss if the air temperature remains constant. When the external temperature equals the surface temperature (skin or clothing), no heat can be lost by conduction; when it exceeds the skin temperature, heat is gained by the body. Movement of the air, by changing the layer of air in contact with the body surface, increases the conduction heat loss when the air temperature is below the temperature of the body surface, but air motion has

\* "Thermal conduction is defined as the process of heat transfer through a material medium in which kinetic energy is transmitted by the particles of the material from particle to particle without gross displacement of the particles." (ASHVE Guide, 1949.)

† In actual practice, the term convection also includes forced air motion as well as the natural circulation of the air.



no effect on conduction heat loss if the temperature of the surface and air are equal.

The second method by which heat may be lost (or gained) by the body is through radiation. Radiation involves the transmission of energy by means of so-called electromagnetic waves. When such radiant energy, especially in the longer wave lengths, is absorbed, heat is produced, and an increase in the temperature of the absorbing body results. This form of heat transfer is commonly called thermal or heat radiation. All objects, which are above absolute zero degrees temperature, are continuously emitting radiant energy. The sun is the chief natural source of radiation. Wave lengths above 700 millimicrons, i.e., in the infrared range, are the most important portion of the spectrum for the production of heat. In addition to the sun, radiant energy in the heating range is emitted in large measure by open fires, molten metal, stoves, and all hot objects. Heat radiation, since it is the same type of energy transfer as visible light, travels at the speed of light, in straight lines, and is independent of the presence of air. The amount of heat radiation which is emitted from any object depends on the temperature, size, and character of the surface of the emitting body. A dull black surface emits the maximum amount of heat radiation for any given temperature. In contrast, aluminum foil at the same temperature emits very little heat radiation. The amount of heat radiation which falls on any object or person depends on the amount of heat radiation emitted by the surrounding objects and on the relation in space of the receiving object to the emitting surfaces. Heat radiation which falls on a surface may be absorbed or reflected by the surface or it may penetrate the surface depending on the character of the surface. When radiant energy falls on the skin or clothing, little penetration or reflection occurs and most of the radiation is absorbed at the surface. A surface with a flat black finish absorbs the maximum amount of infrared radiation. On the other hand, highly polished metals, such as aluminum or even aluminum foil, reflect 90 to 95 per cent of the infrared radiation; some metals also reflect the visible rays.

Since the body is constantly emitting heat radiation and constantly absorbing the same from surrounding objects, the net result may be either a gain or a loss of heat. If the temperature of the body surface is greater than the temperature of the surrounding objects, the body will lose heat. For example, if a person is surrounded by cold outside walls, he will lose more heat by radiation to the walls than he will gain from the walls. If, on the other hand, he is surrounded by walls or objects which are at a higher temperature than the body surface temperature or if he is exposed directly to sunlight, he will gain heat by radiation. Men exposed to large surfaces of heat radiation may have a skin temperature of  $107^{\circ}\text{F}$  when the air temperature is only  $33^{\circ}\text{F}$ . The temperature of the air plays no role in heat transfer by radiation except that it may alter the temperature of the surfaces with which it comes into contact. Foreign materials or water in the air may absorb radiant heat.

The third method by which heat is lost from the body is by evaporation of water from the body surface or from the clothing since, whenever one gram of liquid water is changed to water vapor, it absorbs 0.59 calorie of heat. The rate of evaporation depends on a difference in vapor pressure at the body surface and that in the surrounding space. The vapor pressure at the surface of the body varies with the degree of wetting and with the temperature of the surface. The vapor pressure in the

surrounding space depends on the temperature and relative humidity \* of the air. The higher the temperature, the more water vapor a space can contain at saturation. Evaporation ceases when the relative humidity reaches 100 per cent. Air movement aids evaporation from the body only by replacing the humid layer of air at the body surface with drier air. When the air temperature equals the body surface temperature and the moisture in the air is completely saturated, air movement is of no value in increasing heat loss either by conduction or by evaporation. Under comfortable environmental conditions, when a person is at rest, about 25 per cent of the heat loss is due to evaporation of water which diffuses through the skin (insensible perspiration) and to evaporation of moisture from the respiratory mucosa through the expired air. When sweating occurs, the amount of heat loss by evaporation is greatly increased, and at high temperature, evaporation of sweat is responsible for practically all of the heat lost from the body.

**Physiological Adjustments to High Temperatures.** At normal environmental temperatures, a person who is not engaged in physical work can lose sufficient heat by radiation and conduction without any physiological adjustment, provided there is no major source of radiant heat in the surroundings. As the external temperature increases above normal, certain physiological adjustments take place to facilitate heat loss. The first adjustment is vasodilatation in the skin which increases the circulation and thus the temperature of the skin. Because of the higher skin temperature, the heat loss by radiation and conduction is increased. However, peripheral vasodilatation tends to produce a fall in blood pressure. Under normal conditions, this fall in blood pressure is compensated immediately by an increase in pulse rate, and by a redistribution of the blood. There is also some evidence that dilution of the blood may occur, which leads to an increase in the blood volume and pressure. If the external temperature is further increased so that sufficient heat cannot be lost by conduction and radiation, a second mechanism is brought into play to increase heat loss: the sweat glands become active, and evaporation becomes the important method of heat loss. The temperature at which sweating begins depends on the rate of work, type of clothing worn, and on other factors. Sweating usually starts at a temperature between 81° and 88° F when at rest, but at lower temperatures when working. As much as two liters of sweat per hour, or even more, may be produced. The sweat which runs off the body is of little value in removing heat from the body, since heat is lost only when sweat is evaporated. The rate of sweating varies with a number of factors; i.e., the temperature and humidity of the air, physical work, acclimatization, water intake, condition of the individual, etc. The concentration of sodium chloride in sweat varies with the individual idiosyncrasies, the rate of sweating, the internal and skin temperature, the type and duration of work, the intake of water and salt, and, especially, the degree of acclimatization. Concentrations of NaCl in sweat from 0.03 to 0.6 per cent have been reported by different observers. This great loss of water and salt from the body, if not adequately replaced, may lead to a marked dehydration of the body tissues and reduction in blood volume, even

\* "The relative humidity is the ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature or, in other words, it is the ratio between the amount of moisture actually present in the environment to the amount which would be present if complete saturation occurred at the same temperature." (ASHVE Guide, 1949.)



to the extent of 6 to 8 per cent of the body weight. Drinking of water alone does not restore the blood volume; salt must be taken at the same time. It has been shown that men do not voluntarily replace the water lost by sweating; the sensation of thirst is quite inadequate.

If the temperature and humidity are both high, the body can no longer lose sufficient heat. The body temperature rises, the pulse rate increases, and the blood pressure becomes unstable, usually with a fall in diastolic level. Under extreme conditions, the metabolism increases, thereby leading to a greater heat production. Dehydration accentuates the rise in rectal temperature and pulse rate.

**Acute Clinical Conditions Resulting from Exposure to High Temperature.** Three general clinical conditions, which are directly related to the physiological stresses which have just been described, may result from exposure to high temperatures. They are: heat exhaustion, heat cramps, and heat stroke.

The most common clinical condition resulting from exposure to heat is heat exhaustion (heat collapse or heat prostration). This condition is one of circulatory collapse resulting from a failure of the circulatory system to compensate for the peripheral vasodilatation and dehydration described above. The symptoms may be very mild, with only dizziness, fatigue, and headache, or complete collapse with unconsciousness may occur. The body temperature may be as low as 96° F or it may be normal or slightly elevated. The blood pressure is always low at the time of collapse but may be normal by the time the patient reaches the dispensary. The skin is moist and may be either hot or cold. The blood and urine are usually normal. The treatment is similar to that used in all cases of circulatory collapse and consists of administering intravenous saline and glucose and cardiac stimulants.

The second type of acute clinical condition which results from exposure to heat is heat cramps. This occurs in men who are doing heavy muscular work in high temperatures and who are sweating profusely. The chief symptoms are the painful spasmodic cramps of the skeletal muscles most actively used during the preceding work period. The onset is usually sudden and may not occur until after the end of the work shift. The body temperature may be normal or slightly increased, the pulse rate is increased; the blood pressure, normal; and the skin, hot and moist. The blood is usually so concentrated that it is difficult to secure a blood sample. Analysis of the blood shows a marked fall in sodium and chloride, an increase in phosphorus and calcium, no change in the potassium, and either no change or an increase in the sugar. Heat cramps are due to the fall in sodium chloride in the blood and body dehydration which results from the loss of sweat. In severe cases, saline should be given intravenously; in light cases, water and salt may be taken by mouth. The cramps are relieved at once by such treatment. Administration of intravenous glucose and of drugs is of no value in relieving the cramps.

The third clinical condition which may result from exposure to high environmental temperature is heat stroke or sun stroke. There is no evidence that sun stroke differs from heat stroke; the effects of the sun are entirely due to the radiant heat. Heat stroke is by far the most serious of the clinical heat conditions. The fatality rate is about 40 per cent if the rise in body temperature does not reach 110° F, and 80 per cent or more if it rises above this. Patients with heat stroke often collapse without exhibiting any marked prodromal symptoms. Coma followed by convulsions and active delirium usually occurs. The outstanding feature of heat stroke

is a marked rise in body temperature, usually between  $107^{\circ}$  to  $110^{\circ}$  F, although lower or higher temperatures may occur. The pulse is rapid, the blood pressure often is slightly elevated; the peripheral blood flow is normal; and the skin is usually hot and dry since cessation of sweating usually, although not always, precedes the attack. The blood shows no marked concentration, no fall in sodium and chloride, and no other outstanding changes at first, although later, acidosis and a high nonprotein-nitrogen usually occur. There appears to be no dehydration; in fact, some patients show edema of the tissues. The treatment consists in bringing the body temperature down as rapidly as possible by an ice water bath, an ice pack, or evaporative cooling. There appears to be no reason for the intravenous administration of saline or glucose. Patients suffering from heat stroke must be watched carefully for several days. It is reported that certain cases have shown permanent central nervous system symptoms resulting from the high body temperature.

The etiology of heat stroke is not clearly understood at present, although it is usually attributed to a breakdown in the sweat mechanism.

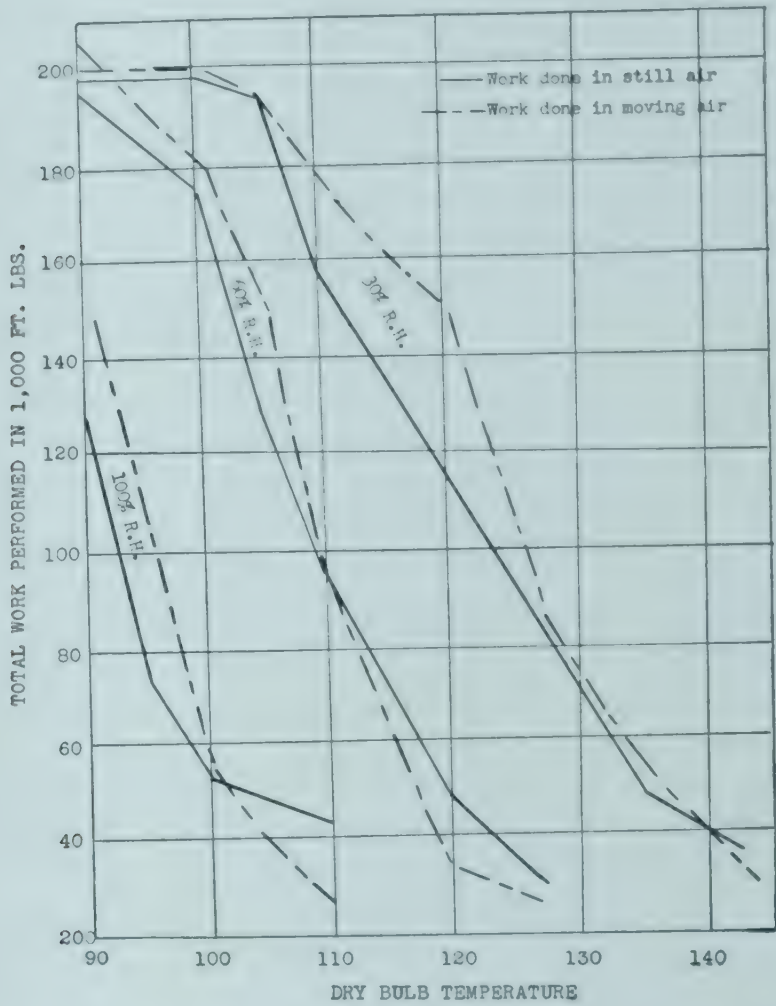
In addition to the three acute systemic conditions which may result from exposure to high temperature, mention must be made of the skin conditions which occur as a result of exposure to high environmental temperatures. Prickly heat or heat rash (*miliaria rubra*) is the most common, and is described as an acute inflammatory disorder of the sweat glands. A second type of skin condition, which is attributed to obstruction of the orifice of the sweat ducts, is called sudamen or *miliaria crystallina*. These skin conditions can be very irritating and annoying especially to persons who live in the tropics.

Exposure to excessive heat radiation or extremely hot air (and, of course, direct contact with hot objects) may cause burning of the skin. Breathing of hot air does not appear to produce damage to the deep lung tissue unless the temperature is sufficiently high to cause burning of the skin and upper respiratory mucosa. It is stated that a person cannot breathe air above  $240^{\circ}$  F ( $105^{\circ}$  C).

**Relation of High Temperature and Humidity to Physical Work.** Muscular work at high environmental temperatures accentuates all of the physiological reactions which result from exposure to heat. Exercise, even in normal temperatures, leads to an increase in heat production and in heart rate and, under some conditions, to a rise in body temperature. At high temperatures, the added heat production, combined with the inability of a body to lose heat, places a severe strain on the body. As a result, the ability to perform heavy physical work is greatly limited, and the effects of high temperature are greatly accentuated. When a person works at high temperature, the pulse rate and body temperature increase to a greater extent than when he is doing the same work at normal temperatures. Even a few minutes of exercise will produce a marked rise in pulse rate. The capacity of a man to work drops off markedly, and under extreme conditions little or no work is possible. The limiting factor under these circumstances does not appear to be a lack of adequate fuel supply to the muscles, a lack of oxygen, or a marked increase in the lactic acid in the blood. Although the body temperature may rise appreciably, the rise in temperature also does not appear to be the controlling factor. Some people believe that a fall in cardiac output, in spite of the rise in pulse rate, is the limiting factor for work in high temperatures.



The decrease in work with increasing temperatures and humidities is shown in Figure 25-1 which is taken from experiments of the American Society of Heating



From McConnell, W. J., and Yaglou, C. P., J. Am. Soc. Heat. & Ventil. Engin., 31:103, 1925.

Fig. 25-1. Average total work subjects were capable of producing in still and moving air experiments.

and Ventilating Engineers (McConnell and Yaglou, 1925). In these investigations the subjects lifted 40-pound weights at the rate of 75 times per five minutes and alternated with five-minute rest intervals until compelled to leave the test chamber. The subjects were capable of performing four times as much work in a temperature of 100° F with a relative humidity of 30 per cent as they could at the same temperature with 100 per cent humidity. When the relative humidity was 60 per cent, the subjects performed five times as much work at a temperature of 90° F as at 120° F. A number of studies in the heavy industries have shown that the output falls off when the temperature becomes very high. There are a few laboratory studies which indicate that muscular coordination may also be impaired at high temperature.

**Acclimatization.** When persons are continuously exposed to high temperature for several days, they gradually become acclimatized to the heat, and tolerate the high temperatures with much less physiological stress. The exact mechanisms re

sponsible for this acclimatization are not well understood at present. Some acclimatization occurs within a few days; further adaptive changes follow upon prolonged exposures of several months to the heat. Upon leaving the hot environment, the acclimatization gradually decreases, although some degree of adaptation remains as long as six weeks.

The importance of acclimatization was well shown during World War II when troops were sent to hot climates for training purposes. Those who were forced to perform heavy physical exercise for long periods immediately on arrival almost invariably developed heat exhaustion. On the other hand, when the work was light at first and then gradually increased in intensity or when the length of the work period was short at first and then gradually increased, the men gradually became acclimatized and avoided all clinical symptoms of heat exhaustion. Furthermore, the latter groups were able to perform heavy physical work for long hours within a few days, whereas the other group was unable to work at all. A general program for developing acclimatization should be followed by all individuals who go into hot climates or hot industries after residing in a cold environment. These persons should not attempt to do heavy physical work for long hours immediately upon exposure to heat but should gradually increase the intensity or duration of their work during the first week of exposure. Likewise, the duration of work periods might profitably be reduced during the first few days of a sudden hot spell in summer.

**Tolerance Limits to High Temperatures.** In the preceding paragraphs, the adjustment of the body to high temperatures and the clinical conditions which result when the thermal stresses become too severe, have been reviewed. It is now necessary to consider the upper limits of physiological adjustment and the maximum temperature conditions which a person might be expected to tolerate without a breakdown in the physiological mechanisms.

**LIMITS OF PHYSIOLOGICAL RESPONSE TO HEAT.** When a man is exposed to extreme heat, the physiological responses eventually reach a point beyond which further readjustment cannot occur, and breakdown ensues. These limits have been determined to some extent.

The upper limit of body temperature which the average person can survive is about 110° F. The limit of effective cardiac acceleration in high temperature when a person is sitting at rest appears to be about 140 beats per minute. While exercising at high temperature, subjects are usually at the borderline of collapse when their heart rate reaches about 180 beats per minute. The cardiac output under thermal stress is able to increase only 1.4 to 1.7 liters per minute, whether a person is at rest or at work. The upper limit of the rate of sweat secretion is about 1,800 grams per hour at rest and about 3,900 grams per hour when exercising. These rates of sweating cannot be maintained for any great length of time. According to Herrington (1949), this rate of sweating represents a water turnover per hour which is equivalent to more than half the normal blood volume.

**UPPER LIMITS OF ENVIRONMENTAL CONDITIONS.** The upper limits of environmental temperature and humidity which man can tolerate for any length of time vary with many factors. However, before discussing these factors and the limits which have been found, it is necessary to decide on the maximum physiological changes which should be accepted as tolerable for more or less continuous exposures. Usually, it is assumed that conditions causing a rise in body temperature over 101° F



and an increase in pulse rate to about 125 beats per minute represent the limits which should be allowed for repeated exposures. For shorter periods, rectal temperatures of 102° F and pulse rates up to about 160 or 170 beats per minute have been considered as limits of tolerance by some authorities.

The upper limits of environmental temperature which man can tolerate depend largely on his condition. Heavy physical work, lack of acclimatization, extensive dehydration, improper clothing, old age, lack of physical fitness, excessive adipose tissue, and a low ratio of body surface area per unit of metabolic tissue all lower his tolerance levels. Obviously, a young acclimatized soldier can tolerate higher temperatures than can an older, stout man accustomed to sedentary work. Unfortunately, most of the studies which have been made to determine the upper limits of environmental temperature which man can endure have been made on young men. Data on older persons and women are lacking. In addition to the condition of the man, the maximum tolerable temperature and humidity vary with the duration of the exposure. Man can tolerate air temperatures as high as 150° F for short periods, whereas, for long periods under some conditions, he cannot even tolerate 85° F. High day temperatures can be tolerated better if sleeping temperatures are low. Sources of heat radiation and air movement also influence the tolerance limits.

A number of investigations have been made to determine the maximum thermal levels which can be endured by man. Some authorities have set the limits in terms of dry bulb temperature and relative humidity, whereas others have specified the limits in wet bulb temperatures.\* The early experiments to determine the upper thermal limits which man can tolerate were performed by Haldane (1905). This distinguished physiologist found that the wet bulb temperature, regardless of the dry bulb temperature, accurately indicated the upper limit of temperature which men could endure without an abnormal rise in rectal temperature. The following wet bulb temperatures were the limits which he reported for the specific conditions studied by him: for men lightly clothed or stripped to the waist when at rest in still air, 88° F; for similar conditions but with a linear air movement of 170 feet per minute, 93° F; for men stripped to the waist and leisurely climbing at the rate of 13 feet per minute in still air, 78° F; and for similar conditions but with air moving at 135 feet per minute, 85° F.

In more recent years, The American Society of Heating and Ventilating Engineers has carried out a number of experiments to determine the upper limits of temperature man can tolerate. Also investigations along this line have been performed in various university laboratories and by the Armed Forces. The results of these studies have been summarized by Yaglou and others (1950) in a report of the Committee on Atmospheric Comfort of the American Public Health Association. These data are reproduced in Tables 25-1 and 25-2 and Figure 25-2. According to this committee: "Young healthy persons, working under the conditions defined in Table 1, are capable of maintaining heat balance after having been ac-

\* The dry bulb temperature is the temperature recorded by the ordinary thermometer and is affected only by the air temperature. The wet bulb temperature is the reading of the thermometer when the bulb is covered with a wet wick and when a strong current of air is passed over the wick. The amount of heat lost by the bulb under these conditions, and thus the reading of the thermometer, is affected by both temperature and humidity. The wet bulb temperature is always below the dry bulb temperature except when the relative humidity is 100 per cent, at which point both temperatures are equal.

Table 25-1. High environmental dry and wet bulb temperatures\* that can be tolerated in daily work by healthy, acclimatized men wearing warm weather clothing

Relative Humidity %	Air Movement					
	15-25 f.p.m.		100 f.p.m.		300 f.p.m.	
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	Dry bulb	Wet bulb
Summer season, light sedentary activities (Eff. temp. 85° F)						
80	89	84	91	85	93	87
60	94	82	96	84	98	85
40	100	79	101	81	103	82
20	109	75	110	75	110	75
5	119	69	118	69	117	68
Summer season, heavy work; M.R. = 240 Cal./m <sup>2</sup> /hr. (88 Btu/sq.ft./hr. (E.T. 80° F)						
80	83	78	86	81	89	83
60	88	76	90	78	93	80
40	93	73	95	75	97	76
20	100	69	101	70	102	70
5	107	64	107	64	106	63
Winter season, light or heavy work (E.T. 75° F)						
80	78	73	81	77	85	79
60	81	71	85	74	88	76
40	86	68	89	70	91	72
20	91	63	93	65	94	66
5	97	58	97	58	97	59

\* Including radiation effect.

Explanation of abbreviations in Tables 25-1 and 25-2:

Eff. temp., E.T. = effective temperature

M.R. = metabolic rate

Cal./m<sup>2</sup>/hr. = calories per square meter per hour

Btu/sq.ft./hr. = British Thermal Units per square foot per hour

1 Btu = 252 calories

ASHVE = American Society of Heating and Ventilating Engineers

USBM = U. S. Bureau of Mines

AMRL = Armored Medical Research Laboratory

m.p.h. = miles per hour

f.p.m. = feet per minute

From Yaglou and others, Thermal Standards in Industry—Report of A.P.H.A. Committee on Atmospheric Comfort. Presented at Annual A.P.H.A. meeting, 1949. Am. J. Pub. Health, 40:no. 5, Pt. II (Year Book), 1950, p. 131.

climatized, with a pulse rate of less than 125 beats per minute and a rectal temperature of less than 101°, provided that the external work performed is not so high as to raise the metabolic rate above 240 Cal/m<sup>2</sup>/hr. This is considered to be a practical rate of work capable of being sustained over a working day without much difficulty to physically fit persons."

Table 25-2 presents the limiting conditions under which distinct heat distress or outright collapse may occur. Figure 25-2 shows the duration of exposure which can be tolerated at very high temperatures.



Table 25-2. Limiting conditions under which distinct heat distress or outright collapse may occur in healthy, acclimatized subjects

Mean eff. temp.	Dry bulb temp. range	Relative humidity range	Rest			Work		
			Tolerance, hours	Terminal pulse	Terminal rectal temp.	Tolerance, hours	Terminal pulse	Terminal rectal temp.

Pittsburgh studies, ASHVE-USBM. Fourteen subjects wearing slacks, socks and shoes

						Raising M.R. = 240 Cal./m <sup>2</sup> /hr. wgt.		
90	90-122	15-100	Indefinite	—	—	1.4-1.8	133-168	100.2-100.5
95	95-145	5-100	> 3.0	—	—	0.9-1.3	140-171	100.4-101.7
100	100-144	15-100	1.4-2.2	122-160	100.2-103.1	0.5-0.8	147-175	100.6-102.0
105	105-157	15-100	0.7-1.0	128-162	100.6-103.1	0.4-0.6	154-176	100.8-102.0
110	110-145	30-100	0.5-0.7	135-165	101.1-103.1	0.3-0.4	161-179	101.0-101.9
115	115-153	30-100	0.4-0.6	143-167	101.6-103.0	0.2-0.3	165-181	101.2-101.7
120	130-160	30-100	0.3-0.5	150-170	102.1-103.0	0.2	175-184	101.4-101.5

University of California studies, Blockley and Taylor. Two subjects, wearing wool-cotton union suits and felt duffel socks

106	180	5	0.7-0.9	150-160	101.7 max.
109	201	3	0.5-0.6		
111.5	221	2	0.4-0.5		
113.5	240	1½	0.3-0.4		

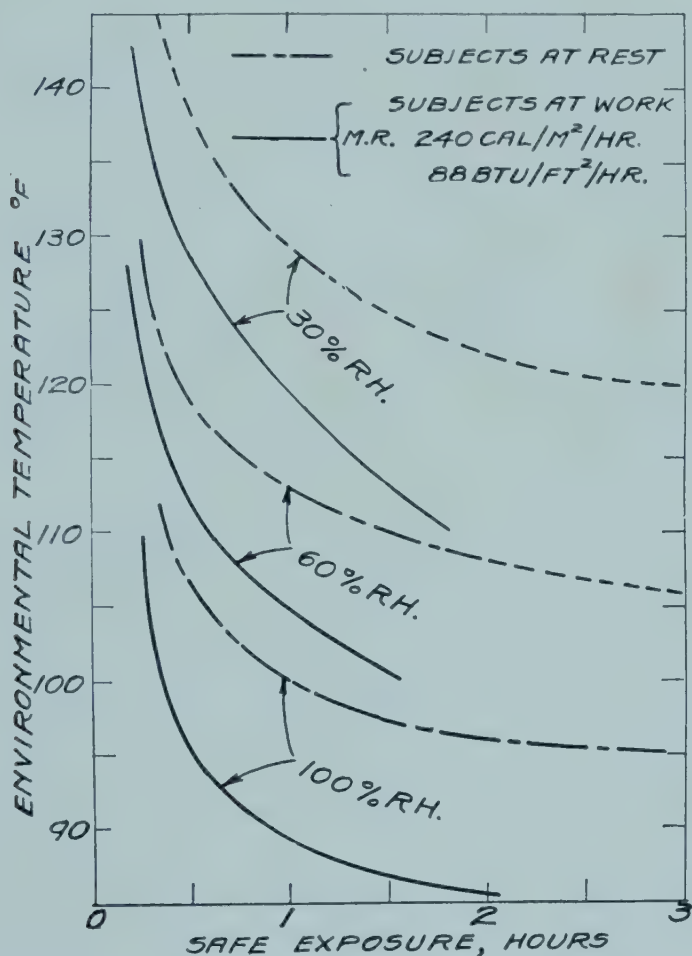
Fort Knox studies, AMRL. Thirteen soldier subjects wearing socks and service shoes. Marching 3 m.p.h. with 20-lb. pack

			M.R. = 145 Cal./m <sup>2</sup> /hr.		
94	94-119	36-100	4	132-142	101.0-102.0
96	96-120	38-100	1-4	144-163	103.0-103.2

From Yaglou and others, Am. J. Pub. Health, 40:no. 5, Pt. II (Year Book), 1950, p. 133

Prevention of Effects of High Temperature. PERSONAL MEASURES. The harmful results of exposure to high temperatures may be avoided by certain preventive measures. The most important personal procedure is to replace the water and salt which are lost from the body through the sweat. The best method is to drink abundant quantities of water containing about 0.1 per cent sodium chloride. If a salt solution is not available, salt tablets may be taken with the water. Some persons develop nausea from salt tablets, especially if the tablets do not dissolve rapidly. Under these conditions, enteric coated or impregnated tablets should be used. Men

working in high temperatures and losing between 5 and 8 liters of sweat per day require at least 15 grams of salt per day. The normal salt intake in food is about 10 grams. It is recommended that an additional 2 to 5 grams of sodium chloride be taken each day. In order to supply 5 grams of salt, 5 liters of 0.1 per cent



From Am. J. Pub. Health, 40:134, 1950. Data from Am. Soc. Heat. & Ventil. Engin.

Fig. 25-2. Thermal standards in industry. Safe exposures in relation to environmental temperature.

NaCl are required or 8 ten-grain tablets with at least 5 liters of water. If men are doing very heavy work or if the temperature is very high, a greater quantity of salt and water will be required. There is no advantage in adding sugar or potassium to the salt tablets nor in taking vitamins.

Another method of reducing the incidence of heat cases is to decrease the amount of physical work and the duration of exposure to hot environments. Alternating periods of work and rest may be desirable, especially if the exposure to heat follows suddenly upon prolonged exposure to cool temperatures. A period of systematic acclimatization, such as discussed under the section on acclimatization, might prove valuable. The severity of heat cases can be prevented by cessation of work and removal from the hot environment as soon as the first signs of heat effects, such as headache, dizziness, nausea, and exhaustion appear. In some instances, it



may be desirable to employ men who are less susceptible to the effects of heat. Procedures for selecting such persons have been worked out by some investigators.

The type of clothing is also important. A few of the principles of clothing design for hot exposures are given in Table 25-3. As little clothing as possible should be worn in hot environments except when exposure to heat radiation exists. White and light colored clothing are desirable since these colors reflect the shorter infrared rays. However, they do not reflect the longer rays; therefore, they are only partly effective against heat radiation. Clothing should be made of material which is thin and light weight and which requires little water for saturation, dries rapidly, and contains little air. Air-ventilated suits are now available for use in hot industries where the worker remains in one location. A complete discussion of the science of clothing in relation to heat regulation has been published recently (Newburgh, 1949). In order to avoid sudden chilling, clothing which has become soaked with perspiration should be changed before a person goes into cooler environments. For personal protection against radiant heat, metal shields, metal lined helmets, and metal treated clothing are most effective. Aluminum foil and aluminum are the best reflectors of radiant heat, and are resistant to ignition. The foil can be pasted onto cloth. Men clad in aluminum suits and protective goggles can withstand a tremendous amount of radiant heat from fires, furnaces, bombs, etc.

When the temperature of the air or the relative humidity are low, heat loss from the body can be increased by the use of local fans. However, air movement, as stated above, is of no value if the temperature and humidity are high.

**MECHANICAL MEASURES FOR REDUCING HEAT EXPOSURES.** There are a number of mechanical procedures for preventing exposure to excessively high temperatures. If heat is being produced by an industrial process, it may be possible to prevent exposure of workers by insulating the process, by isolating it so that only those workers necessary for that process are exposed, by operating the equipment from a distance, and by exhausting the hot air or steam as it is produced. If the building acquires heat only during the day, it can be cooled during the night by exhausting the heated air and replacing it with the cooler night air. This principle is used in private dwellings where large exhaust fans, placed in the attic, are operated at night. On the other hand, if hot air from outside of a building is the source of the heat, the air temperature of the interior can be lowered by insulation of the building with insulating materials or air spaces and by flooding or spraying the roof with water. The latter procedure leads to evaporative cooling of the roof. The interior of buildings may be cooled by circulation of cold water through radiators or pipes in the rooms, and by air-conditioning units which supply cool, dry air. The cooled air may be distributed throughout the entire space or, in industries, it may be directed locally at the worker. The temperature of the air striking the workers should be not less than 80° F, and, for continuous exposure, the velocity should not exceed 200 feet per minute. Short exposures to much higher velocities of air movement are beneficial only in the presence of radiant heat. By providing flexible air ducts, the location of blasts can be regulated so as to avoid chilling of the head, shoulders, and back. Dehumidification of the air which allows greater evaporation of sweat is at times more desirable than cooling of the air.

If the heat exposure is from radiation sources rather than from hot air, other measures are applicable. Radiant energy from the sun reaches the interior of a build-

Table 25-3. Theoretical considerations in the principles of clothing design for the tropics

Conditions	Color	Texture	Thickness	Water Vapor Permeability	Weight	Extent	Openings	Fit	Water Repellency	Underclothes
Solar radiation	Light	Close	Moderate	Moderate to high	Medium	Well covered	Not important	Loose	Nil	Moderately desirable
Radiation from hot objects	Immaterial	Close	Moderate	Moderate to high	Medium	Well covered towards source	Depends upon humidity. Away from source	Loose	Nil	Depends upon humidity
Hot dry air	Immaterial	Close	Moderate to thick according to wind	Moderate	Medium	Well covered	Control-lable	Loose	Nil	Not important
Hot humid air	Immaterial	Open	Thin	High	Light to medium	Minimum	Extensive	Good, not tight. Well cut. No constrictions	Nil unless rain resistance required	Minimum
Tropical rain	Immaterial	Imper-meable to water	Thin	As much as is consistent with water exclusion	Light	Adequate protection	Facing downwards	Loose	Complete superimposed removable covering	

Adapted from Lee, D. H. K., and Lemons, H., Geographical Rev., 39:181, 1949.



ing partly by direct transmission through the glass windows. By the proper orientation of the building in relation to the sun, it is possible to obtain a minimum of solar radiant energy inside the building in summer and a maximum in winter. The transmission of infrared radiation through glass may be avoided by use of heat absorbing glass and by window shades. Outside shades made of aluminum are the most effective. Radiant energy from the sun is absorbed by the building materials (walls and roof) and is then transmitted to the interior by reradiation and conduction. The amount of radiation absorbed depends partly on the color of the surfaces. Dark colored surfaces absorb most of the heat rays. Light colored surfaces do not absorb as much since they reflect the shorter infrared rays (but not the longer rays) which are present in the sun. A much higher percentage reflection is obtained by some of the metals than by other building materials. Aluminum metal, paint, and foil are all excellent materials to prevent the absorption of radiant heat. Furthermore, even when aluminum is heated by conduction, it re-emits very little radiation. The roof or other exterior surfaces may be covered with aluminum metal or paint or the inside of the roof may be lined with aluminum foil. Aluminum materials can be used most effectively to reflect radiant heat not only from the sun but also from hot furnaces and other sources in industries.

### EFFECTS OF LOW TEMPERATURES

**Physiological Reactions to Cold Environments.** When the human body is exposed to a cold environment, two types of physiological adjustments are brought into play in order to maintain the body temperature. In the first place, the heat production is augmented by voluntary movements and by the onset of shivering. It is possible to increase the metabolic rate five to seven times for short periods by shivering, but this increased rate cannot be maintained indefinitely. Shivering is abolished by very low body temperatures, a fall in blood sugar, anoxia, anesthesia, alcoholism, and physical exhaustion. There is evidence also that low temperatures affect the metabolic rate indirectly through the adrenal cortex or thyroid gland. In the second place, the body maintains its temperature when exposed to cold by decreasing the heat loss from the skin. This conservation of heat is accomplished through constriction of the blood vessels in the skin and a reduction in plasma volume. These two mechanisms reduce the blood flow through the skin and thus lower the temperature so that less heat is lost by conduction and radiation. Reduction of surface area by changes in posture, such as "hunching up the body," also assists in reducing heat loss.

Although acclimatization to heat is a well-known physiological process, the problem of physiological acclimatization to cold is subject to controversy.

**Acute Conditions Resulting from Excessive General Body Chilling.** Because of the adaptive mechanisms described above, the body temperature does not usually fall more than 2° to 3° F. If, however, the exposure to the cold air is intense and prolonged or if the body is unable to compensate sufficiently, the body temperature may continue to fall. The pulse rate and blood pressure decrease after an initial rise, the original feeling of cold and pain gives way to numbness and loss of sensations, and muscular weakness and a desire for sleep ensue. When the body temperature reaches 80° F, coma sets in. However, individuals treated with cryotherapy have

survived body temperatures of 80° to 85° F for a week or more without apparent damage to their tissues. Death usually occurs when the body temperature falls to 77° or 70° F. According to Herrington (1949): "on more severe exposure heart failure is apparently the cause of death and is attributed to direct cold injury of the heart and its functional exhaustion due to great increases in blood viscosity." Other authorities have suggested that perhaps solidification of tissue lipoids or failure of respiration may be factors in the cause of death.

If the body is immersed in cold water, rather than cold air, the body temperature falls much more rapidly. If the water temperature is below 60° F, or even below 68° F, heat production cannot keep pace with heat loss, and the body temperature falls until death ensues at internal temperatures of about 77° F.

**Tolerance Limits to Cold.** A number of factors, such as age, amount of adipose tissue, degree of physical fitness, physical exercise, and clothing, affect the ability of man to adjust to cold environmental temperatures and, thus, his chance of survival. The lowest outdoor temperatures in which man can survive depend, of course, on the duration of the exposure. Few data are available on this subject at the present time. However, Yaglou (1950) has estimated the endurable limits as follows: "at +10° F air temperature endurance of inactive persons is reduced to less than 6 hours; at -10° F to about 4 hours, at -40° F to 1½ hours, and at -70° F to 25 minutes. With physical work these limits may be extended." Attempts also have been made to specify the lower limits of ambient air temperature for prolonged thermal comfort. The figures predicted as the lowest temperatures for comfort in dry cold air are shown in Table 25-4.

Table 25-4. Predicted lowest ambient temperature for prolonged thermal comfort

BODILY ACTIVITY	WIND, SKY, ALTITUDE	PREDICTED LOWEST AMBIENT TEMPERATURE FOR PROLONGED THERMAL COMFORT		
		Nude (0 Clo *)	Business Suit (1 Clo)	Arctic Suit (4 Clo)
		°F	°F	°F
Sitting quietly	<i>No wind</i> , shade, sea level	82	70	34
Sitting quietly	<i>5 m.p.h.</i> , shade, sea level	88	76	40
Sitting quietly	<i>25 m.p.h.</i> , shade, sea level	90	78	42
Sitting quietly	<i>5 m.p.h.</i> , <i>shade</i> , sea level	88	76	40
Sitting quietly	<i>5 m.p.h.</i> , <i>sunshine</i> , sea level	76	65	28
Sitting quietly	<i>5 m.p.h.</i> , sunshine, <i>sea level</i>	76	65	28
Sitting quietly	<i>5 m.p.h.</i> , sunshine, <i>20,000 ft.</i>	66	54	17
<i>Sitting quietly</i>	<i>5 m.p.h.</i> , shade, sea level	88	76	40
<i>Walking</i>				
<i>3.5 m.p.h.</i>	<i>5 m.p.h.</i> , shade, sea level	77	53	-20

\* From Belding, H. S., in *Physiology of Heat Regulation and the Science of Clothing*, edited by L. H. Newburgh, Philadelphia, W. B. Saunders Co., 1949, p. 352.

In cold water, the human body cannot survive for even as long periods as in cold air. When the water temperature is 60° F, men can survive only two to five hours. At 40° F water temperature, the rectal temperature rapidly falls 11° or 12° F, and death may occur within one hour. It has been estimated that a man



could probably survive eight hours in water if the temperature was not less than 62° F, whereas, even when nude, he could survive for eight hours in air at 46° F.

**Conditions Resulting from Excessive Local Chilling.** Of greater importance than general body chilling, are the local changes which occur in the extremities (hands and feet) upon exposure to cold. The extremities cool rapidly because of the large surface area relative to the mass of tissue and because of the small quantity of blood circulating through them. Some confusion exists in the terminology which is applied to the various conditions resulting from local cooling of the skin; but, in general, three reactions can be differentiated: (1) acute transient inflammatory reactions, (2) trenchfoot, immersion foot, etc., and (3) frostbite or freezing of the skin.

**ACUTE TRANSIENT INFLAMMATORY REACTIONS.** When the skin of the extremities is exposed to cold, vasoconstriction occurs in the small superficial blood vessels and later in the large arteries. This reaction is followed by an intermittent reactive vasodilatation of the smallest vessels, due, according to Lewis (1941) to the liberation of a histamine-like substance in the tissue acting through an axon reflex. The dilatation leads to a local redness of the skin. A sensation of pain, independent of the cold sensation, arises as the skin temperature falls to 59° F, but at 50° F pain is replaced by numbness and loss of all sensation. Swelling of the skin also occurs; the volume of the affected tissue, such as the finger, may be increased as much as 15 per cent. This acute inflammatory reaction in the extremities subsides within a few hours after removal from the exposure.

**TRENCHFOOT, IMMERSION FOOT, ETC.** Prolonged exposure to cold and wetness may lead to extensive damage to the extremities. The initial reactions are similar to the acute transient reactions with spasm of the terminal arterioles and venules. Later marked dilatation of the capillaries, stagnation of the blood and edema occur. Tissue degeneration may follow. When removed from the exposure, the feet are cold, swollen, waxy white with some cyanotic areas, numb, and anesthetic to pain. Shortly afterwards, the affected parts become red, hyperemic, hot, and swollen. At this stage the skin presents a livid appearance. Later, blebs with extravasations and often gangrene appear. During World War II, many cases of immersion foot occurred among men who were forced to sit for days in crowded lifeboats. The exposure to the cold and wetness, accompanied by the inactivity, led to this condition. During World War I, a similar condition, called trenchfoot, occurred in men who stood for long periods in wet trenches.

**FROSTBITE.** The term frostbite usually is applied to tissue damage which results from exposure to intense cold, whether the damage results from the profound vascular changes (described above under acute transient reactions and trenchfoot), or from actual freezing of the tissues. However, Lewis (1941) suggests that the term be limited to conditions in which actual freezing occurs. The freezing point of the skin is between 0° and -2° C; but the skin rarely freezes until its temperature falls to -5° or -10° C, or even much lower, because of supercooling of the skin. Lewis (1941) claims that supercooling is possible to a greater degree in unwashed skin and is probably related to the relative dryness of the horny layer. Frostbite occurs commonly when the air is dry and well below the freezing temperature. The skin, when frozen, appears pale, dull, opaque, and yellowish. A prickly and itching

sensation develops; vasodilatation leads to local redness, swelling occurs, and usually a wheal is formed over the frozen area. If the freezing period lasts only a few seconds, the wheal disappears after several hours. If freezing continues for a longer period, an extensive exudative inflammation with blister formation results. Prolonged deeper freezing, lasting for some minutes at, for example,  $-15^{\circ}$  or  $-20^{\circ}$  C, leads to necrosis of the tissue and gangrene.

**RECOVERY FROM LOCAL CHILLING.** Rewarming of the tissue in the case of trenchfoot or frostbite is followed by massive edema and hyperemia. The capillaries become packed with red blood cells and stasis occurs. There is no agreement as to whether the accumulation of red cells is a result of loss of fluid or of some special clumping property of the cells. The complex vascular changes during the cooling and rewarming periods and the mechanism of the stasis and necrosis are not well understood. Various methods of treatment have been suggested, but no one procedure has been generally accepted. Three types of conditions after recovery from trenchfoot have been described: excess vasospasm, pain with numbness, and mild chronic inflammation.

**CONTRIBUTING FACTORS.** Damage to the extremities upon exposure to cold is much more likely to occur when there is pressure on the extremities which interferes with the circulation. Tight gloves, shoes, or other clothing heighten the effects of the cold. Immobility of the part also facilitates the effects of cold, wet surroundings.

**Other Effects of Cold.** There are a number of other items which should be mentioned briefly in discussing the effects of cold, one of which is the allergic reaction. Some persons exhibit typical allergic manifestations upon exposure to cold; local reactions involving urticarial wheals and swelling are reported to occur as well as systemic manifestations.

Another subject which should be mentioned is the possible danger of breathing extremely cold air. Experiments on animals have indicated that cold air, even as low as  $-40^{\circ}$  C, when inhaled, is warmed so rapidly in passing through the upper respiratory tract that damage to the lungs is unlikely to occur. Continuous exposure, however, may lead to sublaryngeal tracheitis with obstructive edema.

In addition to the effects of cold on the body tissues, it should be noted that exposure to cold alters the ability to work chiefly because it interferes with the dexterity of the fingers. Lastly, exposure to cold, because it leads to shivering and muscular movement, causes the early onset of fatigue.

**Prevention of the Effects of Cold.** Excessive cooling of the body may be prevented under most circumstances by the proper clothing, by exercise, and by environmental heating. A splendid review of the science of clothing has been published recently (Newburgh, 1949). In brief, it can be said that the clothing should be thick, multilayered, light in weight, and windproof. Warmth depends far more on the amount of air held in the interstices of the cloth than on the kind of fiber. Therefore, thick clothing composed of fibers which are not easily compressed, and which allow air to be trapped but which prevent convection currents, is the best type for cold exposures. The clothing should allow some ventilation next to the skin and be permeable to water vapor. The design of clothing for cold climates presents some difficulties. If the clothing is warm enough for a man when he is resting, it will be too warm for him when exercising. Furthermore, sweat which is produced during



the exercise may be precipitated in the cold outer layers of the clothing. Upon cessation of exercise, rapid evaporation of the moisture in the clothes may lead to chilling. Clothes should be made so that they can be closed tightly around the arms, legs, and neck when the man is resting; but opened when he is exercising. Clothing should be loose fitting; any clothing which restricts the movement of any part of the body or interferes with the circulation of the blood is undesirable. It is most important that foot and hand covering fit very loosely. Electrically heated clothing may be used in some circumstances.

The insulating value of clothing is expressed in a unit called the "clo." It is defined as follows: "The clo is a unit of insulation and is the amount of insulation necessary to maintain comfort and a mean skin temperature of 92° F in a room at 70° F with air movement not over 10 feet per minute, humidity not over 50 per cent, with a metabolism of 50 Calories per square meter per hour. On the assumption that 76 per cent of the heat is lost through the clothing a clo may be defined in physical terms as the amount of insulation that will allow the passage of 1 Calorie per square meter per hour with a temperature gradient of 0.18° C between two surfaces.

$$1 \text{ clo} = \frac{0.18^{\circ} \text{ C}}{\text{cal./sq.m./hr.}}$$

"The ordinary business clothing of men has an insulation value of about 1 clo. The best clothing has in practice a value of about 4 clo per inch of thickness. The theoretical value for absolutely still air has been estimated at 7 clo per inch at 18° C" (Newburgh, 1949).

According to Yaglou and others (1950): "The warmest practical clothing made has an insulation value of about 4.5 Clo, the warmest mittens 1.5 Clo, and the warmest footwear 2.5 Clo. These will not protect the wearer indefinitely in temperatures below the freezing point without physical activity."

The harmful effects of cold may be prevented also by a reduction in the duration of exposure and by alternating periods of exposure and rewarming. Persons with circulatory disturbances of the extremities should not be employed in positions requiring exposure to low temperatures.

## RELATION OF TEMPERATURE AND HUMIDITY TO SUSCEPTIBILITY TO RESPIRATORY INFECTIONS

**Acute Respiratory Infections.** There is no proof at the present time that exposure to high temperature or to low temperature per se increases a person's susceptibility to acute infectious diseases of the respiratory tract, but there is some evidence that a fall in outdoor temperature and chilling, especially following exposure to high temperature, may predispose to acute respiratory infections. A number of statistical studies have been made on the relation of changes in the outdoor temperature to the death rates from respiratory infections. Reed (1924) determined the correlations between death rates and climatic factors. He found that deviations of the mean temperature below normal were associated with high death rates for respiratory diseases at all seasons, but especially in the winter. At this season the correlation coefficients ranged from  $-.4$  to  $-.6$ . Since the correlations were calcu-

lated between temperature deviations of one week and the death rates of the following week, the temperature deviation appears to be associated with the onset of the illness rather than with the termination. Other studies have shown similar results. A negative correlation also has been demonstrated between the incidence of minor respiratory infections and changes in outdoor temperatures.

The relation of climatic factors to the geographic distribution of pneumonia and influenza in the United States also has been studied by the use of correlation coefficients. Herrington and Moriyama (1939) reported that the geographical distribution of bronchopneumonia in persons over one year of age and lobar pneumonia were associated with a low outdoor temperature and a stable climate. Influenza did not appear to be related to climatic factors. The seasonal curve of respiratory diseases also suggests a climatic effect, since the highest rates occur in the cold winter months in both the Northern and Southern Hemispheres. However, it should be noted that none of these climatic studies gives any definite proof that the temperature has a direct effect on resistance of persons to infectious agents. It is possible that the greater incidence of respiratory infections, associated with the low outdoor temperatures, is due to closer contacts with other persons in cold weather when there is a tendency to remain indoors, or to some other indirect effects of climate.

In addition to the climatic studies, some industrial studies support the idea that there is a change in host susceptibility with exposure to changes in temperature and chilling. Morbidity and mortality studies have shown that iron and steel workers and foundry workers have high pneumonia rates. These men are exposed to high temperatures and to sudden changes in temperature. Some of the results of one such study are presented in Table 25-5.

Table 25-5. Frequency of pneumonia according to nature of exposure in a steel plant, 1924-1928

Industrial Exposure	Annual No. of Cases of Pneumonia per 1,000 Men
Heat with wide changes in temperature .....	12.6
Inclement weather .....	13.6
No such exposures .....	3.9

From Brundage, D. K., and others, U. S. Pub. Health Serv. Bull. #202, 1932.

Similarly, men who are exposed to all sorts of outdoor weather conditions, such as in shipyard, quarry and cement works, have high pneumonia rates.

The effects of exposure to cold and to changes in temperature on susceptibility to respiratory infections has been studied on animals. These experiments have yielded contradictory results. Chilling of animals, especially guinea pigs, seems to lower their resistance to spontaneous infections, but not to experimentally induced infections.

The rather common idea that the dry atmosphere of overheated houses in winter is a factor in susceptibility to upper respiratory infections is not supported by experimental or statistical data. Although a low relative humidity may cause drying of the upper respiratory mucosa, there is no evidence at the present time that a low humidity is harmful to health. Variations in relative humidity, however, may affect



the length of time that droplets from the mouth and nose remain suspended in the air and thus indirectly may affect the transmission of respiratory infections. (See Chapter 2.)

**Tuberculosis.** There is no sound evidence at the present time to show that temperature, humidity or, in fact, any of the other factors which make up the climate, influence the susceptibility of either animals or men to tuberculosis or alter the course of the infection. Baetjer and Lange (1928) exposed one group of guinea pigs, inoculated with tubercle bacilli, to a temperature of 80° F and a relative humidity of 80 per cent and another group, similarly inoculated, to a temperature of 69° F and a relative humidity of 45 per cent. The mortality and the extent of tuberculous infection were identical in the two groups. According to other investigators, the development and progress of tuberculosis in guinea pigs is unaffected by artificially induced hyperpyrexia. Repeated exposure to intense cold, likewise, had no effect on tuberculosis in guinea pigs.

The treatment of tuberculous patients with diathermy or inhalation of hot moist air was reported to be without any marked beneficial effects. Human patients with tuberculosis appear to respond to good treatment equally well in all climates. Moriama and Herrington (1939) found that the correlations of tuberculosis mortality with climatic factors were not statistically significant.

## VENTILATION AND AIR CONDITIONING

**Changing Concepts of Ventilation.** During the nineteenth century it was assumed that the discomfort which occurred in close and crowded rooms was due to the chemical composition of the air which the occupants breathed. The undesirable chemical constituents were believed to be either an excess of carbon dioxide from the expired air or a hypothetical toxic substance in the expired air. Some persons thought the effects might be due to a reduction in the oxygen content of the air. On the basis of these ideas, it was considered necessary to supply fresh outdoor air to all schoolrooms and other indoor spaces when large numbers of persons were gathered together. The ventilating engineers believed that an air supply of 30 cubic feet of air per person per minute would be necessary to remove the supposedly toxic substance and maintain a low concentration of carbon dioxide. Hence, in 1895, this ventilation standard was adopted by the American Society of Heating and Ventilating Engineers. At about this same time, physiologists were studying the effects of close and crowded conditions on man. These scientists proved that there was no toxic substance in expired air and that the discomfort and faintness which occurred under such circumstances were not the result of the chemical changes in the air but were due to a failure of the body to lose sufficient heat. Furthermore, it was found that the air leakage in all ordinary buildings was sufficient to prevent any appreciable deficiency of oxygen or accumulation of carbon dioxide. Thus, the physical properties of the air which control heat loss from the body became more important factors in ventilation than the chemical composition of the air, and the early standards of ventilation, based on air supply per person, were no longer tenable.

What, then, are the current standards of ventilation? The desirable objective of ventilation and air conditioning is to maintain indoor conditions which are optimum

for health and comfort and which will prevent the spread of diseases. It is, however, impossible to set standards of ventilation which will prevent the spread of diseases. The relation of atmospheric conditions to the transmission of infectious agents from one person to another is discussed in Chapter 2. A review of the data presented in that discussion makes it evident that ventilation standards cannot be formulated on the basis of biological contamination of the air. Ventilation standards also cannot be set in terms of the chemical composition in the air, except where foreign chemical substances are present. As noted above, the normal constituents of the air do not vary appreciably under any usual circumstances. Only when dusts, gases, and other materials harmful to health are introduced into the air by industrial or other processes, are ventilation standards set in terms of the chemical composition of the air (see Section 6). Since the early physiological experiments showed that the physical properties of the air which control heat loss from the body were responsible for the discomfort, the physical factors have become the basis for modern ventilation standards. The physical factors of the environment which control heat loss from the body are, as discussed elsewhere in this chapter: the temperature, humidity, and movement of the air, and the temperature of the surrounding walls and objects. Although these factors are now accepted as the basis of ventilation and air-conditioning standards, it is not possible to specify the conditions which are optimum for health. Very little is known regarding the effects of temperature, humidity, and air movement on health. However, ventilation requirements can be based on the thermal conditions which place the minimum physiological stress on the body and which produce a sensation of comfort. Comfort is a composite sensation derived partly from a feeling of warmth which is related to the skin temperature, partly from a sense of freshness which depends on the lack of congestion in the upper respiratory mucous membrane, and partly from nerve impulses produced by light fluctuating air currents acting on the skin. A sensation of discomfort arises from too low or too high skin temperatures, from congestion of the respiratory mucosa and from a variety of complex physiological changes in heart rate, body temperature, metabolism, sweating, etc. It is believed that environmental conditions which are comfortable and which do not cause physiological stress favor good health.

**Recommended Thermal Standards.** **AIR TEMPERATURE.** For men who are doing sedentary work, the optimum dry bulb temperature of the air for winter in the cooler areas of the United States varies from 68° to 72° F. Women are more comfortable at about 75° F since they wear lighter clothing and may have a lower heat conductance from the interior to the skin. Older persons and sick individuals are more comfortable at higher temperatures, probably because of poorer circulatory adjustments. Under ordinary resting conditions the majority of persons are comfortable when the skin temperature is between 91° and 93° F, even though the air temperature varies from 55° to 82° F. Skin temperature is not a good measure of comfort when a person is sweating, is doing physical work, or is subjected to sudden changes in temperature.

During physical work, the air temperature must be lower because of the added heat production. However, temperatures below 60° F are not recommended, in general, since when the person ceases work rapid chilling may occur at the lower temperatures. There should not be a difference of more than 2° F in air temperature



between the floor level and head level since larger gradients of the temperature may be uncomfortable.

In summer, when people are acclimatized to hotter environments, temperatures from 75° to 80° F, or even up to 85° F for some persons, are more comfortable. There has been considerable discussion, but very few scientific data, to determine the maximum temperature gradient which a person can tolerate with reasonable comfort when passing from a hot outdoor temperature to a cool air-conditioned interior in summer. Everyone who traveled on trains in the early days of air conditioning, when only the diners were cooled, can remember the discomfort experienced at a temperature of 70° F after having been exposed to temperatures of 85° or 90° F. The ventilating engineers believe that gradients of 10°, 15°, or even 20° F between outdoor and indoor temperatures are satisfactory provided the indoor temperatures are 75° F. The physiologists, on the other hand, believe that 15° and 20° F gradients are undesirable. However, it must be admitted that evidence of any damage to health from such temperature changes in summer has not been published as yet.

**HUMIDITY.** The relative humidity of the environment plays only a small role in comfort except at very low and very high temperatures. At normal temperatures, the skin temperature exceeds the air temperature; hence the vapor pressure at the skin is greater than the vapor pressure in the surroundings, even when the latter is completely saturated. Because of this relationship, changes in humidity are not very important. At higher air temperatures, between about 84° and 93° F, when sweating has begun, the heat loss by evaporation is also fairly constant in spite of variations in relative humidity from 15 to 75 per cent. A rise in humidity tends to decrease evaporation, but the body compensates by increasing the secretion of sweat and by increasing the percentage of skin surface wetted. The increase in sweating balances the decreased evaporation resulting from the rise in humidity and maintains a constant heat loss. On the other hand, when the entire body surface is wetted with sweat, the relative humidity becomes the controlling factor in heat loss. Under these conditions, the humidity should be as low as possible. At low temperatures, the humidity is again important. It is well known that a cold damp climate feels colder than a dry climate with far lower temperatures. It seems probable that, in a wet climate, the moisture is absorbed by the clothing which, in turn, increases the heat conduction of the clothing. Therefore, in cold air it is desirable to have a low humidity. Variations in humidity affect the water content of the upper respiratory tract. In very dry atmospheres, the mucosa of the upper respiratory tract may become very dry. This may be unpleasant to some people. Although the amount of water lost through the expired air is greater at a low humidity, there is no appreciable effect on the total water content of the body. In high humidities, above 80 per cent, the water vapor can be perceived and produces an unpleasant sensation.

**AIR MOVEMENT.** The optimum velocity of air movement varies from 10 to 80 feet per minute depending on the temperature. It is usually stated that air velocities of 25 to 30 feet per minute are desirable for sedentary persons in winter and that velocities of 40 to 50 feet per minute are optimum in summer. Stronger air currents and those affecting only local areas of the body are uncomfortable. If the temperature of the air current is 2° F below the room temperature, air currents of 50 feet per minute may be uncomfortable. At high air temperatures, the air movement should be increased in order to produce greater heat loss, especially when individuals

are doing physical work. However, continuous strong air currents may prove uncomfortable. Some authorities (Yaglou and others, 1950) believe that in hot environments the velocity should not be over 200 feet per minute and the temperature of the air striking the worker should be not less than 80° F. When the temperature and humidity are both high, air movement is of no value in increasing heat loss.

TEMPERATURE OF SURROUNDINGS. The temperature of the surrounding walls and objects must be taken into account in setting ventilation standards. If there are large sources of radiation, such as direct sunlight, open fires, stoves, furnaces, molten metal, etc., the air temperature must be lowered to compensate for the heat gained by the human body from radiation. On the other hand, if there are large cold areas such as cold outside walls, the heat loss by radiation is increased, and the air temperature must be raised. It is stated (ASHVE Guide, 1945) that each degree reduction in the average temperature of the surface of three walls surrounding a room requires a rise of 0.3° F in the dry bulb temperature of the air to maintain the thermal equilibrium. The relationship between varying wall and air temperatures which produce the same degree of heat loss is shown in Table 25-6 and Figure

Table 25-6. The air temperature necessary to compensate for cold walls

Temperature of air and walls in control room	Air temperature (° F) required in cold-wall room, to give warmth equal to that of control room, when three walls were at a temperature of:			
	50° F	55° F	60° F	65° F
80	89.6	87.0	85.1	83.5
70	75.9	74.0	72.5	71.2
60	62.3	61.0	60.0	—

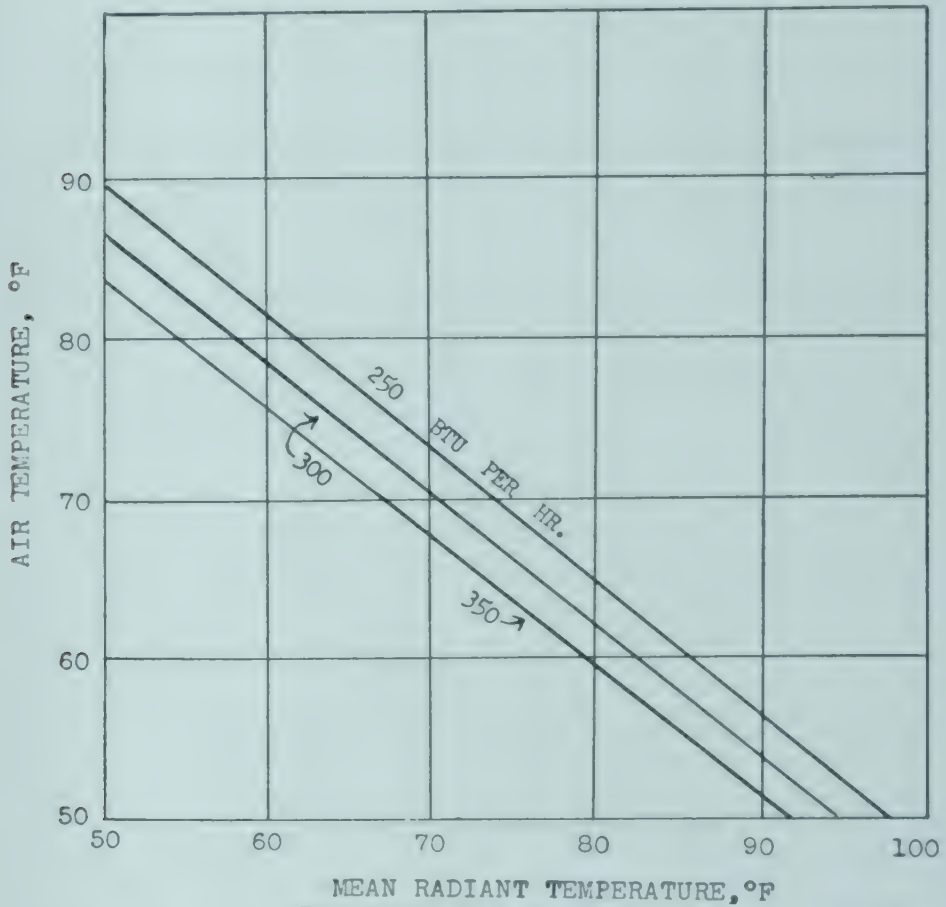
Adapted from Houghton, F. C., and McDermott, P., *Heat, Pip. & Air Cond.*, 53:57, 1933.

25-3. Winslow and others (1938) state that individuals are more comfortable in high temperatures with cooler air and hot walls than with the air and walls at the same temperature, even though the skin and body temperature are the same in both cases. At cold temperatures, persons are more comfortable when the air and walls are the same temperature than when the walls are hot and the air cold with the same overall cooling effect.

Many attempts have been made to express the thermal state of the environment in terms of a single unit, which will combine two or more of the factors of temperature, humidity, air movement, and radiation. The American Society of Heating and Ventilating Engineers' unit—the effective temperature index (°E.T.)—is the only one of these units which has attained sufficient practical use to justify description here. This index was determined by exposing subjects in a test chamber to air at a given temperature with 100 per cent relative humidity. The subjects then moved into an adjoining chamber where a lower humidity and a higher temperature prevailed. If this combination of temperature and humidity produced the same sensation of warmth as the first chamber, this latter combination was designated an effective temperature equal to the dry bulb temperature of the saturated chamber. Any



combination of temperature and humidity giving the same sensation of warmth or cold as a given dry bulb temperature with 100 per cent relative humidity was called an effective temperature equal to this dry bulb reading. The original effective temperature charts were determined for practically still air and for persons who were



From Giesecke, F. E., *Heat., Pip. and Air Cond.*, 12:421, 1940.

Fig. 25-3. Relationship between temperature and mean radiant temperature\* for combined convection and radiant heat losses of 250, 300 or 350 BTU per person.

\* Mean radiant temperature = mean surface temperature of the surrounding walls and objects. This is not actually the arithmetical average of the temperature of the surface but the temperature corresponding to the average rate of heat emission per square foot of surface or the temperature at which a black surface would radiate an intensity equal to the mean observed

not engaged in physical work. Other charts were subsequently prepared taking air movement and physical work into account. Two of the effective temperature scales are reproduced in Figures 25-4 and 25-5. Figure 25-5 is the basic scale applicable to persons at rest and stripped to the waist; Figure 25-4 is the normal scale applicable to persons at rest but dressed in customary indoor winter clothes. The American Society of Heating and Ventilating Engineers Guide (1949) reported that the optimum effective temperature for men and women at rest and normally clothed in winter is 66° E.T. with a range from 63° to 71°; and in summer, 71° E.T. with a range from 66° to 75°. Yaglou (ASHVE Guide, 1949) believes that men at rest and stripped to the waist are most comfortable at 72.5° E.T., with a range of 66° to 82°. It has been found that the effective temperature scale overestimates the

importance of humidity at low temperatures and does not make sufficient allowance for humidity at high temperatures.

The real difficulty in attempting to combine the four factors which control the thermal conditions of the environment lies in the multiple adjustments made by the human body when exposed to changes in temperature. As yet, no one has devised an instrument or any formula which makes adequate allowance for these factors and which can be applied to practical working conditions. Public health authorities working in the field of ventilation recommend that the four factors: temperature, humidity, air movement, and radiant heat be measured separately and that the standards of ventilation be expressed in terms of these four factors.

**Recommended Air Supply.** At the beginning of this discussion, it was pointed out that the original ventilation standards were set in terms of air supply per person per minute. It was also noted that the basis for this standard at the time of its adoption was not correct. With the currently accepted standards of ventilation based on the cooling power of the air, it is obviously not possible to specify a fixed amount of air which should be supplied since this varies with the temperature in the room, the outdoor temperature and the other factors discussed above. However, it is necessary to consider the air supply in relation to the removal of odors, tobacco smoke, and possibly infectious agents. The latter subject is discussed in Chapter 2. Odors and tobacco smoke are often disagreeable and in crowded places should be removed.

Table 25-7. Minimum outdoor air requirements, to remove objectionable body odors under laboratory conditions

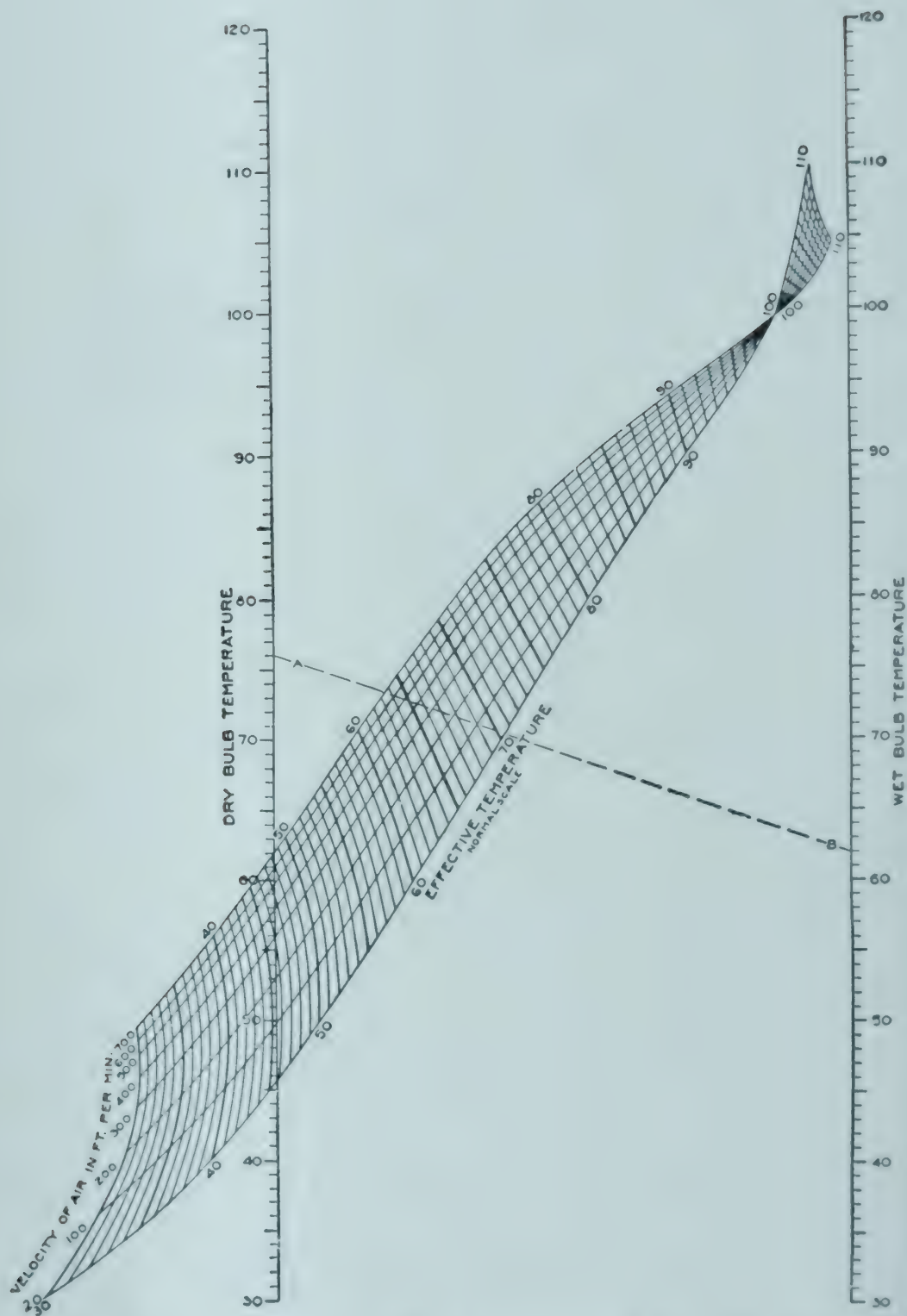
Heating season with or without recirculation. Air not conditioned

Type of Occupants	Air Space Per Person Cu. Ft.	Outdoors Air Supply CFM per Person
Sedentary adults of average socio-economic status . . . .	100	25
	200	16
	300	12
	500	7
Laborers . . . . .	200	23
Grade school children of average socio-economic status.	100	29
	200	21
	300	17
	500	11
Grade school children of lower socio-economic status . .	200	38
Children attending private grade schools . . . . .	100	22

From Heating, Ventilating, Air Conditioning Guide, 1951, Chap. 6, p. 119.

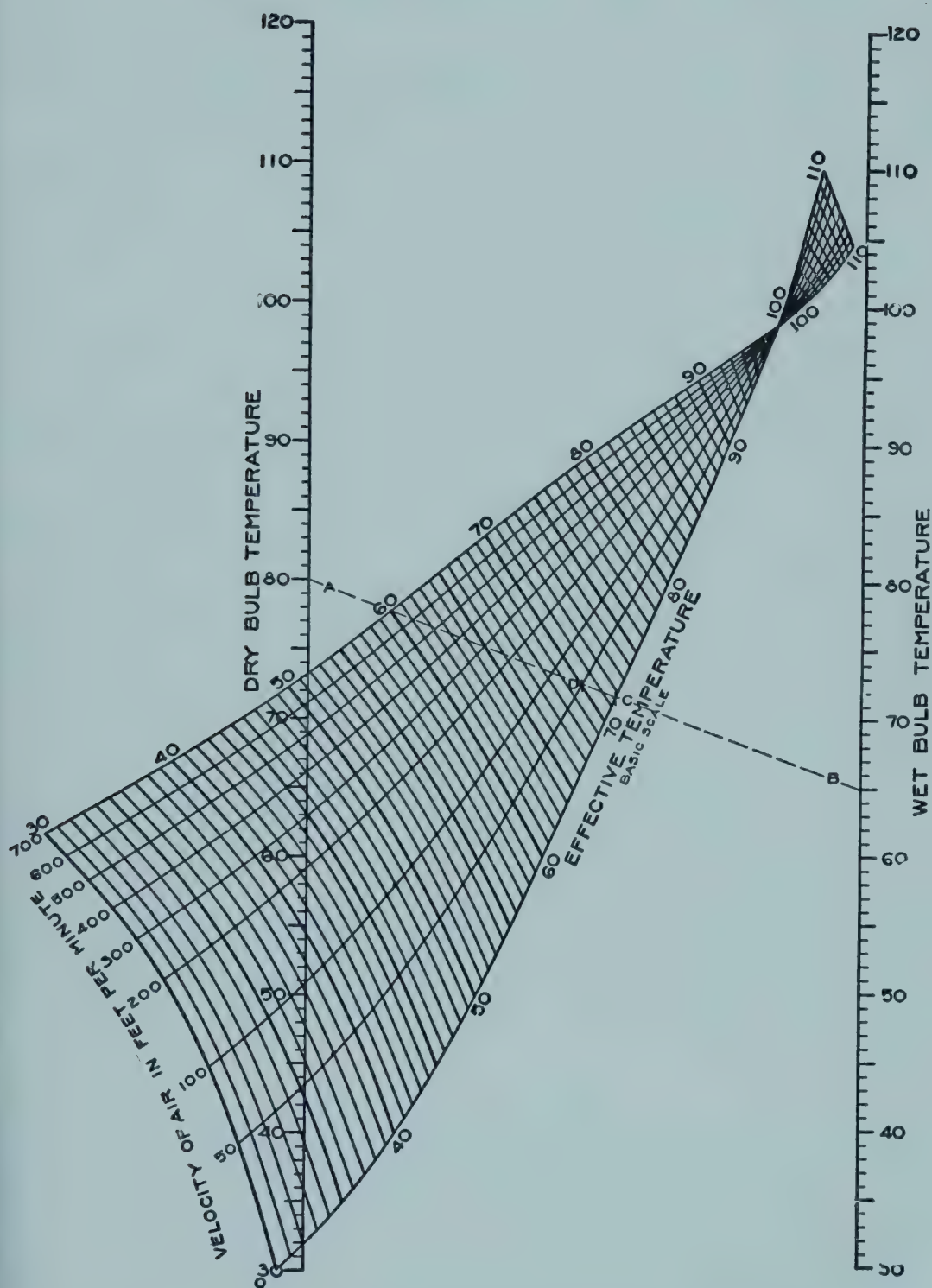
The amount of air supply necessary to remove body odors varies from 10 to 30 cubic feet per person per minute, depending on the condition of the persons in the room and the degree of crowding as shown in Table 25-7. The Committee on Atmospheric Comfort of the American Public Health Association (Yaglou and others, 1950) recommended not less than 15 cubic feet per minute per person for





From Am. Soc. Heat & Ventil. Engin. Guide, 27:227, 1949.

Fig. 25-4. Thermometric chart showing normal scale of effective temperature. Applicable to inhabitants of the United States under following conditions: *clothing*, customary indoor clothing; *activity*, sedentary or light muscular work; *heating methods*, convection type, i.e., warm air, direct steam or hot water radiators, plenum systems.



From Am. Soc. Heat & Ventil. Engin., Transactions, 33:285, 1927.

Fig. 25-5. Thermostatic chart for human beings at rest and stripped to the waist.



persons doing light work and not less than 20 cubic feet per minute per person for persons engaged in heavy work. This air supply probably will be effective in removing tobacco smoke.

On the basis of this discussion, it is evident that under normal conditions, ventilation, either natural or mechanical, is essential chiefly to maintain a normal cooling power of the air and only secondarily to remove body odors and tobacco smoke. In industries or other places where foreign materials harmful to health are present in the air, the ventilation for the removal of these chemical substances becomes of great importance.

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# 26

## RADIATION

### ELECTROMAGNETIC RADIATION

**Nature and Source of Electromagnetic Radiation.** Radiant energy is emitted as a result of internal changes in the atoms. This energy is believed to be given off as discrete packets or quanta of energy. In other words, this radiation may be considered as a stream of particles (or photons as they are called) each carrying a quantum of energy. The quantity of energy in each quantum is related to the frequency (per second) of the radiation and thus to the wave length—the higher the energy value of the quantum, the shorter the wave length. In a vacuum, all electromagnetic radiation has the same velocity, namely,  $3 \times 10^{10}$  cm. per second. Electromagnetic radiation may be classified into seven groups according to the wave lengths. Cosmic, x, and gamma rays have very short wave lengths and very high energy values; ultraviolet radiation, visible light, and infrared radiation have increasingly longer wave lengths and progressively lower energy values; and Hertzian, or radio waves, have very long wave lengths and even lower energy values. The

Table 26-1. Wave lengths of various radiations

	ANGSTRÖMS *
Cosmic rays .....	0.0005
Gamma rays .....	below 1.40
X-rays .....	below 150
Ultraviolet .....	below 4000
Limit of sun's U.V. at earth's surface .....	2920
Visible spectrum .....	4000-7000
Violet .....	4000-4240
Blue .....	4240-4912
Green .....	4912-5750
Maximum visibility .....	5560
Yellow .....	5750-5850
Orange .....	5850-6470
Red .....	6470-7000
Infrared .....	greater than 7000
Hertzian waves .....	beyond $2.20 \times 10^6$

\* To change from Angström units to millimicrons, divide by 10.

Chiefly from Hodgman, C. D., Editor, Handbook of Chemistry and Physics, 32nd edition, Cleveland, Chemical Rubber Pub. Co., 1950-51, p. 2247.

wave length distribution of these various radiations, all of which represent the same type of energy, is shown in Table 26-1. In addition to the distribution of radiant energy according to the frequency or wave length, it should be noted that, at any given wave length, the total intensity of the radiation emitted by the sun or any object also may vary.

The sun, which is the natural source of radiant energy, emits radiations continuously over a very wide range of the spectrum. However, in the passage of sunlight through the atmosphere to the earth, this spectrum is altered because the atmosphere absorbs and scatters many of the sun's rays. The ozone in the upper atmosphere absorbs the shorter ultraviolet wave lengths; the water vapor absorbs some of the infrared wave lengths; and the smoke, dust particles, gas molecules, and water droplets scatter the rays, especially those of shorter wave lengths. The solar spectrum at the earth has a range in wave lengths from 290 millimicrons in the ultraviolet range to over 2,000 millimicrons in the infrared range with a maximum intensity at about 480 millimicrons.

In addition to the sun, every gas, liquid, or solid object at a temperature above absolute zero degrees gives off radiant energy. Solid objects emit almost continuous spectra. At low temperatures only radiation of the longer wave lengths in the infrared range is emitted but as the temperature of the object is increased, more and more of the shorter wave lengths are added. This fact is demonstrated most easily by heating a piece of metal. When steel reaches a temperature of about  $1,700^{\circ}\text{F}$ , it gives off radiation at the red end of the visible spectrum and appears dull red. As the temperature is further increased, the shorter rays also are emitted, until at about  $2,100^{\circ}\text{F}$ , the metal appears white, due to the emission of wave lengths throughout the entire visible range. Gases, when heated, emit radiant energy only at certain wave lengths, which are characteristic of their chemical structure. The wave lengths emitted by gases may be either in the ultraviolet, visible, or infrared range of the spectrum. The mercury vapor discharge tube which is used widely for the production of ultraviolet radiation gives off a number of lines in the ultraviolet range of the spectrum. Ultraviolet radiation is emitted also from carbon arcs, electric welding arcs, and other sources when they are heated to extremely high temperatures. The sources of x-rays and gamma rays will be described later in this chapter under the section dealing with atomic particles and allied radiations.

The effects of radiant energy on the body fall into four distinct types: the heating effects of infrared radiation described in Chapter 25; the effects on the eye of visible radiation; the effects of ultraviolet radiation; and the ionizing effects of x and gamma rays described later in this chapter in connection with the atomic radiations.

## ILLUMINATION

**Sources of Visible Light.** Radiant energy in the visible range is emitted by the sun and by certain substances when heated to a sufficiently high temperature. The wave lengths of radiant energy which stimulate the retina and produce a sensation of light range from about 390 millimicrons to 770 millimicrons (see Table 26-1). Wave lengths somewhat shorter than 390 millimicrons may be perceived, but the sensitivity of the retina to these shorter wave lengths is slight. The intensity of the sunlight just outside the earth's atmosphere is greatest at about 480 millimicrons, i.e., at the shorter end of the visible spectrum. The visible light which reaches the earth from the sun varies in intensity with the time of the day, the season of the year, and the degree of atmospheric pollution.

In addition to the sun, which is the natural source of visible radiation, radiant energy for lighting purposes may be produced by heating solids such as tungsten filaments, or by electrical discharge through a gas such as mercury or neon. In the



ordinary incandescent electric light bulbs, the tungsten filament is heated to the temperature at which visible radiation is emitted. However, these bulbs are very inefficient because the greater part of their radiant energy falls in the infrared range. Furthermore, since the intensity of the radiation in the visible portion of the spectrum increases with an increase in wave length, the color of the light is predominantly yellow. In fluorescent bulbs, mercury vapor is heated, but, since the wave lengths given off by this substance are chiefly in the ultraviolet range, the bulbs must be lined with phosphors which absorb the short wave lengths and re-emit them in the visible range. The wave lengths which are re-emitted depend on the chemical nature of the phosphor. It is now possible to obtain fluorescent bulbs which have their maximum intensity of radiation at various wave lengths or bulbs which emit rays at all visible wave lengths so that the light is somewhat similar to daylight in its spectral distribution. Fluorescent bulbs emit the greater part of their radiant energy in the visible range and very little in the infrared range; hence, they are cool and efficient. A very small amount of ultraviolet radiation is emitted from fluorescent bulbs, but the phosphors and the glass itself absorb almost all of this radiation.

**Units for Expressing the Amount of Light.** The amount of visible radiation (light) which is emitted by a luminous object, such as an electric light bulb, is measured in terms of candle power based on a standard international candle, the equivalent of which is maintained at the Bureau of Standards in Washington. The amount of illumination which falls on a surface from a light source is expressed in terms of foot-candles. One foot-candle of illumination is the intensity of illumination at any point on a surface one foot away from a light source of one candle power. The illumination falling on a surface varies inversely as the square of the distance from the light source. The total amount of light which falls on one square foot of surface, all points of which are one foot from a light source of one standard candle, is called one lumen, i.e., the lumen is the term used to measure light flux. The brightness of the light source or of an object which is reflecting light is usually expressed in terms of foot-lamberts or candles per square inch. One foot-lambert is equivalent to one lumen emitted per square foot of the light source. One candle per square inch is the candle power emitted per square inch of light source. Detailed definitions of these and other units used in illumination are as follows: \*

### INTENSITY

**candle.** The international candle is the unit of luminous intensity and is an arbitrary standard maintained by certain governments. The amount of light emitted by a light source can be determined in terms of this unit. An ordinary candle about an inch in diameter provides roughly one candle power in a horizontal direction.

### LUMINOUS FLUX

**lumen.** The unit of light (or luminous) flux emitted in a unit solid-angle (steradian) from a uniform point source of one international candle. Such a source emits 4 lumens because, as a simple matter of geometry, there are 4 unit solid angles or steradians surrounding a point. A lumen is the total light flux on a surface of unit area all points of which are at a unit distance from a uniform point source of one international candle. If the foregoing unit is one foot it is obvious that a foot-candle is equivalent to one lumen per square foot.

\* Chiefly from Luckiesh and Moss, *The Science of Seeing*, New York, D. Van Nostrand Company, Inc., 1937, pages 318-319.

## LUMINOUS EFFICIENCY

**lumens per watt.** A term expressing the luminous efficiency of an electric light source.

## ILLUMINATION

**foot-candle.** The foot-candle is the unit of illumination. The level of illumination upon a surface varies (1) inversely as the square of distance from the light source of small size relative to the distance; (2) directly with the candle power of the source in the direction toward the surface; and (3) with the cosine of the angle of incidence of the light upon the surface. The illumination (foot-candles) and the diffuse reflection factor of a surface determine the brightness of a diffusely reflecting surface. A foot-candle is approximately the illumination on a small area of vertical surface one foot from an ordinary candle. One foot-candle equals one lumen incident per square foot.

**lux.** A lux is one lumen incident per square meter.

## BRIGHTNESS

**lambert.** Brightness of perfectly diffusing surface emitting or reflecting one lumen per square centimeter.

**foot-lambert.** Brightness of perfectly diffusing surface emitting or reflecting one lumen per square foot.

**candle power per square inch.** Brightness of perfectly diffusing surface emitting or reflecting light equivalent to one candle per square inch.

A lambert = 1 lumen emitted per sq. cm.  
 = 1000 millilamberts (ml)  
 = 929 foot-lamberts (fl)  
 = 2.054 candles per sq. in.  
 = 0.3183 candles per sq. cm.

A millilambert = 0.929 foot-lambert or 0.929 lumens emitted per sq. ft.  
 = 0.00205 candle per sq. in.  
 = 0.001 lambert

A candle per square inch = 452 foot-lamberts  
 = 0.487 lambert  
 = 487 millilamberts

A candle per square cm. = 3.1416 lamberts  
 A foot-lambert = 1 lumen emitted per sq. ft.  
 = 0.00221 candle per sq. in.  
 = 1.076 millilamberts

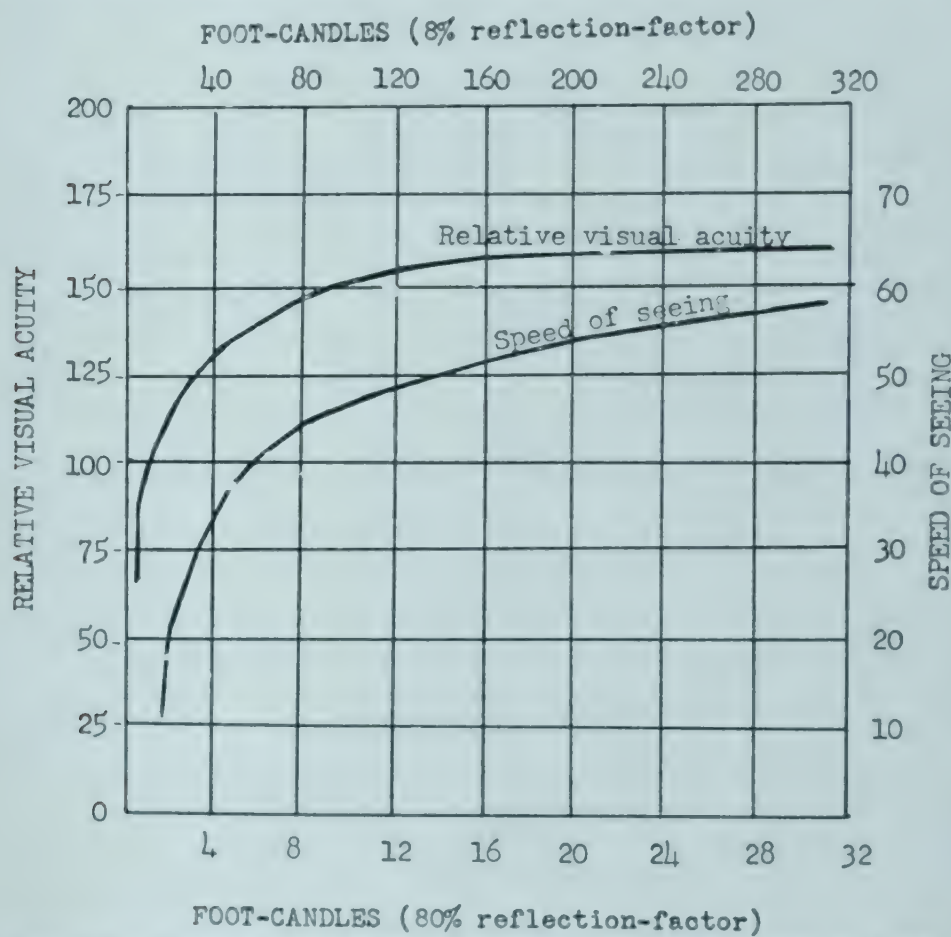
**General Principles of Good Illumination.** INTENSITY OF ILLUMINATION. Sufficient illumination is essential for acuteness of vision (visual acuity), for maximum speed of seeing, for prevention of eye fatigue and eye strain, and, thus, for efficient work and prevention of accidents. Definite proof that poor illumination will lead to permanent eye injury is lacking, but some evidence indicates that a higher incidence of refractive errors, especially myopia, exists among persons who perform close eye work at very low levels of illumination than among persons who work under good illumination. Some authorities believe that the extremely low levels of illumination in coal mines may be a factor in the production of miners' nystagmus, a condition which is prevalent in Great Britain but not in the United States. In addition to the physiological and clinical considerations, it is believed that the character of the illumination affects psychological reactions.

Standards of illumination usually are set in terms of the amount of illumination which falls on the work area. However, since vision depends on the light reaching the eye, the important consideration is not the amount of illumination on the desk or work bench but the amount of light which is reflected to the eye. For example, if there are 50 foot-candles of illumination falling on a white object which reflects about 80 per cent of the visible light, then 40 foot-candles of illumination will be



reflected toward the eye. If the same amount of light falls on a dark object which reflects 20 per cent of the light, only 10 foot-candles of illumination will be reflected to the eye. Hence it is necessary to specify different standards of illumination for different circumstances depending on the amount of light which is reflected from each work area.

Authorities have differed on the amount of illumination which is essential for vision. In general, it can be said that visual acuity and speed of vision increase markedly with an increase in illumination up to about 10 foot-candles, and then increase more slowly up to about 20 foot-candles, as shown in Figure 26-1. The



Adapted from Luckiesh, M., and Moss, F. K., *Seeing, A Partnership of Lighting and Vision*. Courtesy of The Williams & Wilkins Company

Fig. 26-1. The relationship between relative visual acuity and intensity of illumination and speed of seeing at various levels of illumination. Note: If the reflection-factor of the background against which a black object is viewed is 80 per cent, the lower scale is applicable, for a reflection-factor of 8 per cent the upper scale is used.

rate of improvement with higher levels of illumination appears to be low. These data are based on visual tasks where the background had a reflection factor of 80 per cent and where there was optimum contrast in color (black letters on a white background). Hence, 15-20 foot-candles can be accepted as a basic minimum level of illumination for satisfactory vision under optimum conditions. When the reflection factor is reduced, as in work on dark colors, or when the contrast in color between the object and its background is reduced, higher levels of illumination are necessary for good visual acuity and speed of vision, as shown in the upper scale

in the graph. Higher levels are required also for continuous eye work and for fine work, i.e., when the size of the object is very small. Individuals with poor vision or eye defects require more illumination than those with normal eyesight. Hence, although 15-20 foot-candles of illumination are considered the basic minimum, many tasks require more illumination. It is generally recommended that, when the contrast in color and brightness between the object and the immediate background is good and when the object being viewed is the size of normal print, the lighting for continuous eye work should supply a minimum of 30 foot-candles on the object. Where poor contrasts exist or the size of the object is small, the minimum illumination requirement should be set at 50 foot-candles. Even higher levels are necessary under certain conditions, such as in printing and typesetting, or when working on black objects. The American Standards Association (1952) has published *Standard Practice for Industrial Lighting*; The Illuminating Engineering Society (1950), *Recommended Practice of Daylighting*; and the American Medical Association, Council on Physical Medicine (1950), *Basic Requirements in School Lighting* by Tinker.

**BRIGHTNESS AND GLARE.** The amount of light reaching the eye from a light source or by reflection from an object is commonly designated as the "brightness" of the source or object and is usually expressed in foot-lamberts. Although the eye can adapt itself to very high levels of brightness, such as daylight out of doors, it cannot tolerate great contrasts in brightness between the central field of vision and the surrounding area. Such contrasts interfere with vision and may produce an uncomfortable sensation. In viewing an object against its surroundings, the visual acuity is greatest when the surrounding area has the same brightness as the central field of vision. The brightness of the central field of vision should never be less than that of the surroundings. On the other hand, the brightness contrast between the central field of vision, subtending an angle of one minute at the eye, and the immediate surroundings, assuming the latter to be an area which subtends an angle of 60 degrees, should not exceed a ratio of 10:1. Brightness ratios smaller than 5:1, even 3:1, are more desirable for continuous work. Contrasts in brightness within an angle of 30 degrees are especially uncomfortable. Greater contrasts in brightness can be tolerated between the central and peripheral fields of vision, but even here the contrasts in brightness should not be great. For example, the brightness of the ceiling should not be more than 10 times as bright as that of the task area. In order to avoid contrasts in brightness, good general illumination, rather than only local lighting on the work, must be provided throughout the entire area.

Brightness contrasts are produced also when bright light sources are in the field of view. If the eye is adapted to a high level of illumination and the contrast is not great, a bright light in the field of vision does not produce discomfort, e.g., when viewing an automobile headlight during daylight; if the eye is not adapted to bright light or if the contrast in brightness between the light and the surroundings is great, as an automobile headlight at night, an uncomfortable glare sensation is produced. The degree of the glare sensation depends on the distance of the eye from the light source, the brightness of the light source in relation to that of its surroundings, and the position of the light source in the field of vision in relation to that of the object on which the eye is focused. Excessive reflection from shiny surfaces, so-called reflected glare, produces an uncomfortable sensation and may completely obliterate the outline of an object. These localized bright spots, whether they be due to unpro-



ected light sources or to reflected glare, markedly reduce critical vision. Hence, bare light bulbs should never be permitted in the field of vision.

**DIFFERENCES IN ILLUMINATION WHEN PASSING FROM ONE AREA TO ANOTHER.** Great differences in illumination between one work space and another or between a work area and a hallway are dangerous if people are required to move from one space to the other. When passing from a brightly lighted area to one with a low level of illumination, the visual acuity is markedly decreased until dark adaptation has occurred. Although some adaptation occurs fairly rapidly it requires almost one-half hour for complete readjustment of vision to dim light. During the readjustment period the ability of the eye to see clearly is so reduced that the danger of accidents is increased. It is because of this physiological fact that relatively high levels of illumination are recommended for stairs, hallways, storage rooms, etc. Adaptation requires only a few minutes when passing from a dimly lighted space to one at a high level of illumination.

**COLOR OF LIGHT AND SURROUNDINGS, SURFACE FINISH.** A contrast in color between the object and its immediate background is important; the more definite the color contrast, the greater the visual acuity and speed of vision. The value of color contrast is due partly to the dissimilarity in color and partly to differences in the amount of light reflected by the different colors. Recognition of an object becomes most difficult when a black object is viewed against a black background. Here differences in texture and shadows are necessary for vision. Higher levels of illumination are required where the color contrast is reduced.

The color quality of the light from the common illuminants has little or no effect on visual discrimination and, hence, is not very important, except where a particular color is essential for the work, as long as sufficient light reaches the eye. When artificial light is used to supplement daylight, it is desirable to have the artificial light as nearly like daylight as possible.

The color and finish of the walls, ceiling, furniture, and machinery are of great importance in illumination because the amount of light reflected is determined chiefly by the color. Table 26-2 shows the variation in the reflection of visible light by different colors and materials. In areas where good visual functioning is required, it is recommended that the colors of the surroundings be selected so that the following percentage of reflection is obtained: from ceilings, 75 to 85 per cent; from walls, 50 to 60 per cent; from school desks, 35 to 50 per cent; from office desks, 30 to 35 per cent; from machines 20 to 30 per cent; and from floors, 15 to 30 per cent. In order to obtain good diffusion of light and to avoid glare spots, a flat finish is recommended. All polished specular surfaces should be eliminated. The light should be uniformly distributed and harsh shadows should be avoided.

Multiple or contrasting colors often are used for accident prevention, e.g., to indicate moving parts of machines, edges of steps, steam lines and other dangerous objects.

**Recommendations of Types of Artificial and Natural Lighting. ARTIFICIAL ILLUMINATION.** It is evident from the discussion given above that a basic amount of general illumination, about 15 to 20 foot-candles, must be supplied to all areas of a room in order to prevent great contrasts in brightness. Certain situations will require higher levels of illumination. Additional light may be provided in some cases, by raising the general level of illumination throughout the area or, in other cases, by supplying local lighting units. Local or supplemental lighting, in addition

Table 26-2. Reflection factors of typical paint, paper, wood finishes and other materials for interiors

COLOR	PERCENTAGE OF LIGHT REFLECTED
Paints and papers	
White	85
Light	
Cream	75
Gray	75
Yellow	75
Buff	70
Green	65
Blue	55
Medium	
Yellow	65
Buff	63
Gray	55
Green	52
Blue	35
Dark	
Gray	30
Red	13
Brown	10
Blue	8
Green	7
Wood finish	
Maple	42
Satinwood	34
English oak	17
Walnut	16
Mahogany	12
Other materials	
White blotting paper	82
White drawing paper	80
Ordinary foolscap	70
Cream paper	56
Plain deal wood (clean)	45
Yellow wallpaper	40
Medium green wallpaper	18
Dark brown wallpaper	13
Dark green wallpaper	5
Black cloth	1
Black velvet	0.4

o general lighting, is necessary when high levels of illumination are required, when illumination is needed in specific areas not accessible to general lighting, where the light must come from a particular angle, where hand readjustments are needed, where shadows are required, for the prevention of reflected glare, and for other circumstances. Supplementary lighting sources should be arranged so that persons in the vicinity are not exposed to excessively bright spots of light. Local lighting without general illumination is undesirable for the reasons discussed above.

Four types of lighting fixtures for general illumination are available: (1) totally indirect units, in which all of the light is reflected to the ceiling; (2) totally direct units, in which practically all of the light is reflected downward; (3) semi-indirect units, in which part of the light falls on the ceiling and upper side walls and part is directed downward; and (4) totally enclosed units, in which the light is radiated in all directions.



Totally indirect units are most desirable, where such units can be used, since they give an even diffuse illumination throughout an area and produce no shadows, no direct excessive brightness, and no reflected glare. However, they can be used only when the ceiling is at a normal height and is painted white for good reflection. Furthermore, very high levels of illumination cannot be obtained with totally indirect units without excessive brightness of the ceiling. Indirect units are uneconomical to operate and deteriorate rapidly due to the accumulation of dirt in the reflectors. Direct lighting units are more economical than other types and are less likely to deteriorate due to dirt. However, they give great contrasts in illumination, cast harsh shadows, frequently give excess brightness in the field of view, and produce dark ceilings with little general diffuse light. They are used chiefly for local lighting and in shops where the ceilings are too high and dark for other types of units. When adequately equipped with diffusers, they may be used in other areas. Semi-indirect and totally enclosed units are the most practical types for general illumination under usual conditions. Care must be taken that direct, semi-indirect, and enclosed units are properly designed and placed so as to avoid excess brightness in the field of view. Large units having a lower candle power per square inch, such as long tubular fluorescent lights, give less concentrated lighting than round tungsten filament bulbs which have a higher brightness per unit area (see Table 26-3). However, large units with moderate brightness also may cause discomfort

Table 26-3. Brightness of natural and artificial light sources

LIGHT SOURCE	BRIGHTNESS	
	FOOT-LAMBERTS	CANDLES PER SQUARE INCH
Sun as observed at earth's surface .....	450,000,000	1,000,000.1
Full moon, clear sky .....	1,500	3.7
1000-watt Type H-6 mercury lamp .....	104,000,000	230,000.1
400-watt Type H-1 mercury lamp .....	443,000	980.1
Brightest spot on bulb of		
500-watt tungsten-filament lamp .....	131,000	290.1
100-watt tungsten-filament lamp .....	58,800	130.0
40-watt tungsten-filament lamp .....	24,800	55.0
30-watt fluorescent, 1-inch tube (white) .....	2,400	5.3
40-watt white fluorescent, 1½-inch tube .....	1,750	3.9
100-watt white fluorescent, 2⅛-inch tube .....	2,180	4.8

From Taylor, A. H., *Illum. Eng.*, 37:19, 194

if placed directly in the field of view. Exposed bulbs should never be allowed within the field of view. When fluorescent bulbs are used on alternating current, two bulbs must be used together, arranged to prevent the cycle flicker or stroboscopic effect.

Since all lighting units become less efficient with time, chiefly due to the accumulation of dirt, the illumination on the work table may be reduced 25 per cent or even 50 per cent in a short period. Allowance for depreciation should be made in the initial installation especially in areas where dusts, smoke, and fumes exist. All types of units require continuous maintenance.

NATURAL ILLUMINATION. Daylighting, if properly arranged, may be a very effective source of good illumination in a room. However, much more difficulty is encountered in designing for daylighting than for artificial lighting. The amount of daylight reaching a room varies with the location and orientation of the building with the presence of surrounding buildings, and with the time of day, the season

the weather, and the degree of atmospheric pollution. Furthermore, whereas artificial lighting can be evenly spaced throughout a room and directed as desired, daylight is available only from certain areas, and its distribution is more difficult to control. Because of these variable factors, only a few general recommendations for providing daylight illumination can be given.

Windows facing south give maximum heat for cold climates but considerable glare; those facing north are advised for warm climates. The glass area should be at least 20 per cent of the floor area of the room. The tops of the windows should be as near the ceiling as possible, since the higher the windows, the more effectively does the light reach the opposite side of the room. An increase in the height of a window produces a much greater increase in illumination than a proportional increase in the width. The width of the room should not be more than approximately twice the distance from the floor to the top of the window when windows are only on one side of the room because of the rapid decrease in illumination across the room. Too often the illumination near a window is excessively bright while the illumination in another part of the room is below the minimum required for good vision. Windows on two sides of the room are desirable, but where windows are only on one side of a room the glass area should extend the full length of the room, if possible. It is recommended that windows should not be in the field of view for normal working conditions. The size and position of monitors and skylights also must be related to the size of the building. Since direct sunlight often produces excessive brightness, it is necessary to provide some means of sunlight control, such as venetian blinds, shades, louvres, outside projectors, glass block, etc. For maximum reflection and diffusion, the interior of rooms should be painted in light colors. Where feasible, the outside walls of neighboring buildings situated opposite the windows can be painted a light color in order to increase the light reflected to the room. Supplementary artificial lighting is necessary for use when daylight is reduced.

A complete discussion of recommended practices for daylighting in schools, factories, offices, and homes has been published by the Committee on Daylighting of the Illuminating Engineering Society (1950).

### ULTRAVIOLET RADIATION \*

**Ultraviolet Radiation from the Sun.** The spectral range of ultraviolet radiation begins at wave lengths of about 390 millimicrons and continues down toward the shorter wave lengths. Wave lengths between 390 and 310 millimicrons are referred to as near ultraviolet, whereas those which are below 310 millimicrons in length are considered as far ultraviolet. At the surface of the earth, the ultraviolet radiation from the sun extends only to wave lengths of about 290 millimicrons. The amount of ultraviolet radiation which reaches the earth from the sun varies with the season, time of day, latitude, altitude, and composition of the earth's atmosphere. The intensity of ultraviolet radiation from the sun is greater at noon than at any other time of the day and is greater in summer than in winter. These variations are due to the changes in the position of the earth in relation to the sun and to the resulting

\* A comprehensive survey of the subject has been published: *Radiation Biology*, Vol. 2, *Ultraviolet and Related Radiations*, Hollaender, A., Editor, New York, McGraw-Hill Book Co., Inc., 1955.



differences in the thickness of the air mass through which the sun's rays must pass to reach the earth. The visible rays of the sun penetrate the air mass readily, but the ultraviolet radiation is greatly absorbed by the ozone in the upper atmosphere. Hence, as the thickness of the air mass varies, the amount of ultraviolet radiation reaching the earth will vary to a greater extent than the visible light. At noon, when the sun is directly overhead (i.e., at zenith), the thickness of the air mass is at a minimum; when the sun is at  $60^\circ$  (i.e., four hours from the zenith), the thickness of the air mass is twice as great as at the zenith, so that much less ultraviolet radiation reaches the earth at this time than at noon. For this reason, individuals are not likely to receive a sunburn in the late afternoon even though the visible rays of the sun appear as bright as at noon. Similarly, seasonal changes in ultraviolet radiation result from the differences in the thickness of the ozone layer through which the sun's rays must pass at different seasons. According to Luckiesh and others (1944): "The total amount of erythema or anti-rachitic ultraviolet energy received in the six-month period from October to March, inclusive, is only about 10 per cent greater than that received in the single month of June or July. Furthermore, the total erythema or anti-rachitic energy recorded for December is only 1 per cent of that for the whole year." The amount of ultraviolet radiation is greater at high altitudes than at sea level because the impurities in the earth's atmosphere absorb a part of the sunlight. The rays of the sun, especially the shorter visible and ultraviolet wave lengths, are scattered and reflected to the earth by the constituents of the atmosphere as "sky radiation." On a clear day in a temperate climate, "sky radiation" may contribute as much as 50 per cent of the total ultraviolet radiation which reaches the earth. Because of the indirect reflection from the clouds and sky, the amount of ultraviolet radiation at the earth may be greater on days when the sky is covered by high thin cirrus clouds than on cloudless days. For this reason individuals often receive a greater sunburn on a cloudy day than on a clear day. Since snow reflects about 75 per cent of the ultraviolet radiation, persons skiing often get severe sunburns even on the underside of the nose which has no direct exposure to the sunlight.

**General Effects of Ultraviolet Radiation.** Before discussing the specific effects of ultraviolet radiation on the tissues of the body, it is well to consider the general effects of this type of radiation on cells. Ultraviolet radiation does not penetrate the body tissues more than a few millimeters but is absorbed entirely at the surface of the body. Therefore, it can exert a direct effect only on the superficial organs of the body, namely, the skin and the eyes; all other effects must be the result of changes in these tissues. When ultraviolet radiation is absorbed by the cells, the radiant energy initiates a photochemical reaction. According to Blum (1945), the type of chemical reaction which follows "is determined by the kind of molecule present in the environing system as well as by the activated molecule itself." The type of photochemical reaction produced is characteristic of the specific wave lengths of the ultraviolet radiation which are absorbed. For the most part ultraviolet radiation causes injury to the cells as a result of its destructive action on proteins or nucleic acid. The degenerative changes in the cell may affect both the nucleus and the cytoplasm.

Visible radiation, like ultraviolet radiation, produces a photochemical change in the rods and cones of the retina which absorb this radiation. In contrast, infrared

radiation, when absorbed, does not produce a chemical reaction but only increases the kinetic energy of the molecules, and, hence, the temperature of the tissue.

**Effect of Ultraviolet Radiation on the Skin.** ERYTHEMA AND SUNBURN. The penetration of the skin by ultraviolet, visible, and near infrared radiation is shown in Table 26-4. From this table it is evident that none of the ultraviolet radiation penetrates to the subcutaneous tissue. The wave lengths in the extreme ultraviolet are absorbed in the outer layer of the skin, the corneum, which is about 0.03 mm. in thickness. Of the near ultraviolet, about 50 per cent is absorbed in the epidermal layer (the corneum plus the Malpighian layer) which is only 0.05 mm. thick, and the remainder is absorbed in the corium which extends only to a depth of 2 mm. The greater part of the ultraviolet radiation does not penetrate deeply enough to reach the blood vessels of the skin. When the skin is exposed directly to ultraviolet radiation, injury occurs to the epidermal cells, chiefly those in the Malpighian layer. A dilator substance, which resembles histamine but does not appear to be histamine, is either produced in the corneum or is liberated in the breakdown of the cells. This dilator substance diffuses into the papillary layer and causes dilatation of the minute blood vessels, which, in turn, is responsible for the local reddening or erythema of the skin. The erythema does not begin until after a latent period of at least one-half hour, or usually longer, and is limited to the area actually exposed to the ultraviolet radiation. With severe doses, an increase in capillary permeability, edema, and swelling of the tissue may occur. These reactions reach a maximum on the second day. At the same time an erythematous flare may extend beyond the exposed areas. Blistering and desquamation of the skin may follow later, and, in very severe cases, ulceration of the dermis may result. The most interesting reaction in the skin following exposure to ultraviolet radiation is the formation of melanin, the pigment which is responsible for sun tan. Following exposure to ultraviolet radiation, the melanin which is normally present in the Malpighian layer migrates into the corneum. Later more melanin is formed. The wave lengths in the ultraviolet which are most effective in producing the erythema and sun tan are about 297 millimicrons. Subsequently, a darkening of the sun tan pigment may be caused by longer wave lengths, about 300 to 420 millimicrons. The final reaction to the ultraviolet burn is a thickening of all layers of the epidermis. This reaction is apparently a protective mechanism to prevent further injury to the skin by ultraviolet radiation. The tanning of the skin possibly exerts some protection also, but the immunity conferred by this mechanism is believed to be quite secondary to that brought about by the thickening of the skin. The extent of the reaction to ultraviolet radiation depends on the duration and intensity of the exposure and on individual susceptibility. Negroes are much less susceptible to ultraviolet radiation than are white-skinned persons, possibly due to a more uniform distribution of pigment throughout the epidermis or to a greater thickness of the corneum.

**CANCER OF THE SKIN IN RELATION TO ULTRAVIOLET RADIATION.** Considerable evidence, both experimental and epidemiological, exists to indicate that repeated exposure to ultraviolet radiation may cause cancer of the skin. Cancer of the skin can be induced in mice and rats upon exposure to ultraviolet radiation. Skin cancer in man occurs most frequently in those parts of the skin which are exposed to the sunlight. The Negro skin, which is less susceptible to the effects of ultraviolet radiation than white skin, is also less susceptible to skin cancer. It is reported that men in



Table 26-4. Light distribution in the layers of the skin

The number 100 designates the applied intensity. The encircled numbers represent percentages absorbed in each layer. The numbers in the narrow zones between layers represent the percentages of the original intensities transmitted through the layer above. Variations occur in different samples from same subject and from different subjects.

Layer	$\lambda$ mm.	200	250	280	300	400	550	750	1,000	(1,400)	$\mu\mu$		
		100	100	100	100	100	100	100	100	100	Applied		
Corneum	.03	(100)	(81)	(85)	(66)	(20)	(13)	(22)	(29)	+ (56)	Absorbed and reflected		
		0	19	15	34	80	87	78	71	44	Transmitted		
+ Malpighii	.05	(0)	(8)	(6)	(18)	(23)	(10)	(13)	(6)	(16)	Absorbed		
		0	11	9	16	57	77	65	65	28	Transmitted		
+ Corium	2.00	(0)	(11)	(9)	(16)	(56)	(72)	(44)	(48)	(20)	Absorbed		
		0	0	0	0	1	5	21	17	8	Transmitted		
+ Subcutaneous	25.00	(0)	(0)	(0)	(0)	(1)	(5)	(20)	(17)	(8)	Absorbed		
		0	0	0	0	0	0	1	0	0	Transmitted		
General Remarks	Extreme Ultraviolet	Far Ultraviolet				Near Ultraviolet		Visible Violet Green Red		Near Infrared		Far Infrared	
	All absorbed by corneum. No radiation reaching germinativum.		Greatest absorption in stratum corneum. Some radiation reaches corium (papillae).				Relatively large absorption in stratum Malpighii.				Minimum absorption in stratum corneum. Most radiation absorbed in corium.		Strongly increasing absorption in upper layers, decreasing in lower layers.
													Practically no penetration.
													Practically no penetration.

the Navy and those who are engaged in occupations, such as forestry and agriculture, which involve exposure to the sun, have excessively high rates of skin cancer. A recent survey by the Public Health Service indicated that cancer of the skin and lip is more prevalent in the southern than in the northern part of the United States. Blum (1945) considers that this distribution may be related to a difference in the degree of exposure to ultraviolet radiation. Although none of these facts alone prove that ultraviolet radiation causes cancer of the skin, all together they are suggestive of an etiological relationship.

**RELATION OF ULTRAVIOLET RADIATION TO VITAMIN D.** The role of ultraviolet light in the production of Vitamin D, and thus on the prevention of rickets, is well known. Vitamin D is formed by the action of ultraviolet radiation on 7-dehydrocholesterol or on some very closely allied steroid compound. It is believed that this photochemical reaction occurs in the corneum. Wave lengths shorter than 320 millimicrons (chiefly about 280) are most effective in producing this reaction.

**EFFECTS OF ULTRAVIOLET, INTENSE VISIBLE, AND INFRARED RADIATION ON THE EYE.** Ultraviolet radiation is absorbed chiefly by the outer surface of the eye, the cornea and conjunctiva, which absorb all wave lengths below 295 and, to some extent, wave lengths up to 320 millimicrons. The lens completely absorbs the wave lengths between 295 and 315 millimicrons and partially absorbs those between 315 and 380 millimicrons. The degree of absorption by the lens varies with age, being greater in older persons than in younger persons. Wave lengths between 390 and about 1,400 millimicrons reach the retina, and in young persons wave lengths as short as 315 millimicrons may penetrate to the retina. Wave lengths between 390 and 760 millimicrons produce vision; the longer wave lengths cause only heat effects. No wave lengths longer than 1,400 millimicrons penetrate to the retina since these are entirely absorbed by the anterior portions of the eye.

Since the shorter wave lengths are absorbed by the conjunctiva and cornea, the chief effect of exposure of the eye to ultraviolet radiation is a conjunctivitis accompanied by photophobia. A great number of cases of conjunctivitis, commonly known as flash burns, occurred in the shipyards during World War II as a result of exposure to the ultraviolet radiation produced in electric arc welding. The inflammation of the conjunctiva appears several hours after the exposure and reaches its height in about 6 to 12 hours depending on the dose. The symptoms consist in pain and a feeling as though a foreign body were in the eye. Necrosis of the cells and edema of the conjunctiva, cornea, and eyelids occur. If the exposure is very severe, opacities and ulcers of the cornea may result. The condition usually clears completely in several days. Wave lengths of about 305 millimicrons appear to be responsible for this reaction. Eclipse blindness may result from gazing directly at the sun. This condition is apparently due to heat coagulation of the retina by the infrared radiation in the sun, although intense visible radiation may contribute to this. Recovery usually occurs, although the scotoma may be permanent. Snow blindness, which results from excessive exposure to the rays of the sun plus those which are reflected by the snow, consists of an inflammation of the conjunctiva and cornea with photophobia, chiefly due to the ultraviolet radiation, and retinal scotoma, the latter probably due to the effect of the infrared and intense visible rays on the retina. The possible role of ultraviolet and infrared radiation in the production of cataract is not clear. Clark (1935, 1936) has shown that the lens protein *in vitro* is denatured by ultraviolet radiation and that, in the presence of



calcium, opacity develops if the material is subsequently heated to 40° C. Blum (1945) states that wave lengths shorter than 320 millimicrons, if sufficiently intense, can injure the lens epithelium. There is no proof, however, that these reactions cause cataract in man. Glass blower's cataract, which has been reported in England, has been attributed to prolonged exposure to intense infrared radiation.

In order to protect the eyes against ultraviolet, infrared, or excessive visible radiation, glasses which filter out the harmful wave lengths should be worn. The United States Bureau of Standards has established specifications for glasses which will protect against excessive sunlight and certain types of radiation exposures in industries. This agency also has numbered the various shades of filter lenses which correspond to specific spectral transmittances (Stair, 1948). Lenses which reduce the intensity of visible radiation should be used only where exposure to excessive sunlight or glare occurs. The use of tinted lenses inside of homes and offices is not recommended since the level of illumination indoors is low. The use of dark glasses at night for reducing the glare from automobile headlights also is considered inadvisable since the visibility of all other objects is reduced. In selecting glasses for industrial exposures, it should be noted that glasses which reduce visible light may not remove either the ultraviolet or infrared radiation produced in the industrial process. Glasses for protection against radiant energy in industry should be selected in accordance with the specifications of the Bureau of Standards.

**Other Effects of Ultraviolet Radiation.** Since ultraviolet radiation is entirely absorbed by the skin and eyes, any effect on the internal tissues of the body must be due entirely to indirect effects resulting from changes in the skin. Therefore, it is not surprising to find that contradictory and uncertain results have been reported to follow exposure to ultraviolet radiation. Ultraviolet radiation has little if any effect on metabolism. The effect on the blood cells is variable and depends on the type and extent of the exposure. In general, it is claimed that exposure to ultraviolet radiation leads to a slight increase in the red cells, white cells, and platelets.

In spite of the popular opinion that ultraviolet irradiation of the skin and the resulting suntan are beneficial to health and increase resistance to infectious diseases, there are no data to support this view. Animal experiments in which rats, mice, and rabbits were irradiated with ultraviolet radiation before or after or both before and after infection with pneumococci, *B. leprosepticum*, and other organisms have been negative. Studies on the effects of ultraviolet radiation on pulmonary tuberculosis in animals have yielded chiefly negative, although somewhat contradictory, results (Rich, 1944). Studies on man have shown no beneficial effects of irradiation with ultraviolet rays on susceptibility to acute respiratory infections. In one study (Doull and others, 1931) it was found that biweekly irradiation of adult did not reduce the incidence or severity of common colds in this group as compared with a non-irradiated control group. During World War II, when many persons in England worked under artificial lighting due to "blackout conditions," an experiment was performed to determine the effects of ultraviolet light treatment on the health of clerical and industrial workers and miners. Persons treated with ultraviolet radiation did not differ from those not so treated in respect to the incidence of sickness or to the duration of colds (Colebrook, 1946). On the other hand, the use of ultraviolet radiation in the treatment of some skin conditions has been favorably reported. Ultraviolet radiation, especially that between 250 and 280 millimicrons, exerts a marked bactericidal effect. The value of ultraviolet radiation

in preventing the transmission of infectious agents through air and water is discussed elsewhere in this book.

In view of the fact that ultraviolet radiation does not appear to be beneficial to health except in the prevention of rickets and in view of the fact that it may exert a harmful effect on the skin and eyes, the indiscriminate use of ultraviolet lamps in homes and industries should be discouraged. Treatment with ultraviolet radiation for the prevention and cure of rickets should be under the direction of a physician. Because ordinary window glass absorbs all of the antirachitic ultraviolet radiation, it has been suggested that ultraviolet transmitting glass be installed in schools and homes. However, under these circumstances, only children sitting in the direct sunlight coming through such glass will receive any appreciable amount of ultraviolet radiation. Other children in the room who sit outside of the range of direct sunlight would get as much ultraviolet exposure from two minutes outdoors in the sun at noon as they would receive after 20 hours in this room (Clark, 1933). Thus, the installation of ultraviolet transmitting glass is not recommended for schools or private dwellings. Under some circumstances, this glass may be used advantageously in hospitals, sanatoria, and the like.

## ATOMIC PARTICLES AND IONIZING RADIATIONS

**Source and Nature of Atomic Particles and Ionizing Radiations.** When atoms disintegrate spontaneously or are subject to fission or are bombarded with high energy particles, the atoms may emit one or more types of discrete particles and/or some radiant energy. These particles and radiations are usually classified all together as ionizing radiations. In order to understand the effects of these radiations, it is necessary to review the structure of the atom and the nature of these particles and radiations.

**STRUCTURE OF THE ATOM.** According to the classical theory, the atom consists of a tiny, heavy nucleus surrounded by a vacuum in which electrons move like planets about the sun. These electrons, known as planetary or orbital electrons, whirl around the nucleus in orbits which are located at the outer portion of the space. The distance between the nucleus and the orbit of the nearest encircling electron is a gap which is greater in proportion to the size of the nucleus and electrons than the space between the sun and the orbit of the earth. The nuclei of all atoms (except hydrogen) are composed of protons and neutrons. The protons have a mass of about  $1.66 \times 10^{-24}$  gm. and carry a unit positive electrical charge. The neutrons also have a similar mass but are electrically neutral particles. The electrons have a mass which is only 1/1850th of the proton mass and they have a unit negative electrical charge. The number of negatively charged electrons circling around the nucleus is equal to the number of positively charged protons, hence, the atom as a whole has no electrical charge. The atomic weight of the atom is the sum of the mass of the protons plus the mass of the neutrons. The atomic number is equal to the number of protons. The number of protons, i.e., the atomic number, and not the atomic weight determines the chemical properties of an element. The simplest atom, that of hydrogen, has one planetary electron and a nucleus with one proton, but no neutron. Heavy hydrogen has, in addition, one neutron in the nucleus. Helium atoms have two protons and two neutrons in the nucleus and two electrons circling in the outer orbit. All other atoms have structures similar to the



helium atom except that the number of protons, neutrons and electrons are greater.

**RADIOACTIVE ISOTOPES.** The isotopes of elements are chemically the same as the element and their nuclei contain the same number of protons but they differ from one another in the number of neutrons. For example, uranium 235 has 92 protons, 92 electrons and 143 neutrons; uranium 238 has the same number of protons and electrons but 146 neutrons.

Most elements present in nature exist in two or more stable isotopic forms, although some unstable isotopes, such as radium, occur naturally. In recent years unstable isotopes of all known elements have been produced. If the ratio of neutrons to protons in the nucleus of an atom lies within a certain limited range, the atom will be stable. If the ratio falls outside of this range, the atom will be unstable. The unstable nucleus undergoes spontaneous changes in an effort to attain stability, i.e., it emits atomic particles and in some cases gamma rays. These unstable atoms are called radioactive isotopes, or radioisotopes, and the spontaneous changes which take place in the unstable atomic nucleus are known as radioactive decay. Each radioisotope decays at a characteristic rate which is expressed in terms of its half-life, or the time required for the activity of a given quantity of a radioactive material to decay to half its initial value. The half-life has a definite value irrespective of the amount of active material originally present. Some radioactive isotopes have a half-life of many years, whereas others have a half-life of seconds. The half-life of a radioisotope is very important from a health viewpoint. Isotopes which decay rapidly into stable atoms produce ionizing radiations for only a short time and present relatively no problem in waste disposal. Those with long half-lives remain active for years and when taken into the body continue to produce damage until they are excreted. These slowly decaying isotopes present a serious public health problem in waste disposal since, if indiscriminately discharged, they could contaminate the water, soil or air for generations.

**ATOMIC PARTICLES AND RADIATIONS.** The nuclear particles which may be emitted from an atom include alpha particles, negative beta particles, positive beta particles or positrons, neutrons, protons, mesotrons, neutrinos and some other less well known types. The last few types are not well understood at the present time and will not be included in this discussion. In addition, electrons from the orbit may be emitted from the atom by internal conversion of gamma rays. The alpha particles are composed of two protons and two neutrons and thus are the same as the nucleus of a helium atom. Alpha particles are produced by the spontaneous disintegration of certain radioactive substances, e.g., radium, and are artificially produced by the bombardment of certain elements by neutrons. Alpha particles produce intense ionization but penetrate only 5 to 10 cm. of air or 0.1 mm. of tissue. Alpha particles which are produced adjacent to the body surface are entirely absorbed in the cornified epithelium of the skin. Hence, sources outside of the body constitute no great danger to health. If, however, alpha emitters, such as radium, are ingested or inhaled, great damage may be done to the tissues which are in close contact with these radioactive materials.

Beta particles are either high speed electrons or positrons which are ejected from the nucleus of an unstable atom. The beta particles are not considered as present in the nucleus but as created in the nucleus at the instant of disintegration. Often gamma rays are emitted simultaneously with the beta particles. The gamma rays may dislodge and eject planetary electrons which then act like beta particles.

Negative beta particles are emitted from natural radioactive elements, as from the disintegration products of radium, and from many unstable radioactive materials which are produced artificially. Beta particles produce ionization, but their effect is only about  $1/100$ th as severe for a given depth of penetration as that caused by alpha particles. Beta particles vary in their degree of penetration of air from about 1 cm. up to 15 meters. They penetrate only about 1 to 3 cm. of tissue. Thus, when beta rays are emitted close to the skin, the germinal epithelium and the upper layers of the derma will be harmed but the deeper tissues will not be affected. When beta emitters are ingested or inhaled, they constitute a serious internal hazard. Positive beta particles (positrons) are emitted in the decay of some artificially radioactive elements. These positive beta particles are similar to negative beta particles except that they carry a positive charge. Each positive beta particle combines with an electron and yields two gamma rays. Thus, the effects of exposure to positive beta particles are similar to the effects of exposure to negative beta particles plus gamma rays.

Neutrons are elementary atomic particles which form part of the nuclei of all atoms except hydrogen. Neutrons which travel at fast speed (fast neutrons) and those which travel at slow speed (slow neutrons) are produced as a result of atomic fission in a chain reacting pile. Fast neutrons can be liberated also by bombardment of beryllium with high energy particles. Fast neutrons can easily penetrate some substances like lead but are stopped by water. If the neutron collides with a hydrogen nucleus, this nucleus, or proton, is ejected. Slow neutrons react with some of the atomic nuclei of the substances through which they are passing. New elements or isotopes are formed with the liberation of gamma rays or protons. Neutrons in themselves do not produce ionization but they cause severe ionization indirectly through the formation of protons and gamma rays.

The proton is identical with the nucleus of the hydrogen atom. Protons are never emitted spontaneously by radioactive materials but are produced by the action of neutrons on light elements. They produce extensive ionization in a manner similar to alpha particles.

In addition to the particles which may be ejected from an atom, two types of radiant energy, the neutrino and the photon of electromagnetic radiation may be emitted by the atomic nucleus. The neutrino is a radiation which has never been detected and hence will not be considered here. The electromagnetic radiations which are emitted from the nucleus of the atom are the gamma rays and, under some circumstances, x-rays. These rays have exceedingly short wave lengths as shown in Table 26-1. Gamma rays are emitted from the atomic nucleus in the spontaneous decay of natural and artificially produced radioactive substances. They are usually produced in association with the emission of an alpha particle or a beta particle. Gamma rays are formed also in the fission of an atomic nucleus and whenever a positron and an electron combine. Gamma rays of themselves do not produce ionization but they cause the ejection of high speed electrons from the orbit of atoms near which they pass. These electrons in turn produce ionization. Gamma rays penetrate the air and tissues readily and thus produce harmful effects on the deep tissues of the body as well as on the skin. However, the ionizing power of gamma rays, for a given depth of tissue, is only about  $1/10,000$ th as great as that of alpha rays. X-rays are similar in their action to that of gamma rays. Since these radiations are generally of longer wave length than the gamma rays and have a



lower energy value, their ionizing power is less. X-rays are formed when a stream of fast electrons, moving in a vacuum, strikes a metal target. Unlike gamma rays, x-rays are not formed in the nucleus of the atom but by a shift in the position of electrons between the orbits; the energy lost is given off as x-radiation.

Atomic particles and gamma rays are produced also in the explosion of atomic bombs. It is stated (Glasstone and others, 1950) that "the explosion of an atomic bomb is accompanied by the emission of nuclear radiations consisting of gamma rays, neutrons, beta particles and a small proportion of alpha particles. The neutrons and some of the gamma rays are emitted in the actual fission process, that is to say, simultaneously with the explosion, while the remainder of the gamma radiation and the beta particles are liberated as the fission products decay. The alpha particles result from the normal radioactive decay of the plutonium 239 or uranium 235 which has not undergone fission." Radioactivity also may be induced in various elements normally present in the earth or in the sea by the neutrons which are liberated during the explosion if the explosion occurs underground or underwater or close to the earth. These induced radioactive isotopes usually decay by emission of beta particles accompanied by gamma radiation.

**UNITS AND TERMINOLOGY.** The units which are used to express the energy of atomic particles and ionizing radiations are somewhat complex. In fact, the measurement of these radiations in terms of their biological effectiveness presents a number of problems. The standard unit for determining the quantity of energy liberated in x- or gamma rays is the "roentgen" which is defined in terms of the ionization produced in a known mass or volume of unrestricted air. The roentgen is not applicable to measurement of the energy of atomic particles nor does it measure the biological effectiveness of ionizing radiations. As a result of these difficulties, two new units have been introduced: the roentgen equivalent physical (rep) and the roentgen equivalent man (rem) (see Radiological Terminology, below).

Various instruments for measuring the number of atomic particles and for measuring the intensity of x- and gamma rays are now available commercially.

Following is a list of definitions of terms which are currently used in the field of atomic energy.

#### RADIOLOGICAL TERMINOLOGY \*

**Ionizing radiation** is electromagnetic radiation (consisting of photons) or particulate radiation (consisting of electrons, neutrons, protons, etc.) usually of high energy but in any case capable of ionizing air, directly or indirectly.

**X-rays** (sometimes "x-radiation") are electromagnetic ionizing radiation. In radiology x-rays are often classified according to the voltage at which they are produced. The following classification according to voltage range is generally understood:

**Low-voltage x-rays:** Voltage range up to 140 kv.

**High-voltage x-rays:** Voltage range 140 to 250 kv.

**Supervoltage x-rays:** Voltage range 250 kv. to 3 Mv.

**Multimillion-volt x-rays:** Voltage higher than 3 Mv.

In this connection it is convenient to distinguish between the voltage at which the x-rays are produced and the energy of the x-ray photon. Kv or Mv refers to the former, and kev or Mev refers to the photon energy. When the radiation is monochromatic, kev or Mev is generally used.

**Roentgen rays** are x-rays usually produced by bombarding a (metallic) target with high-speed electrons in a suitable device. Gamma rays are x-rays originating in the nuclei of atoms.

\* Quoted directly from "Permissible Dose From External Sources of Ionizing Radiation," Handbook 59, National Bureau of Standards, September 1954.

In general "x-rays" and "roentgen rays" are used interchangeably in radiology. The distinction indicated here is made simply for convenience, since it does away with the cumbersome repetition of the expression "x-rays and gamma rays."

**Quality of x-rays.** The term "quality" refers in a general way to the penetrating power of an x-ray beam. *Soft x-rays* are x-rays of low penetrating power; *hard x-rays* are x-rays of high penetrating power.

**Half-value layer (HVL).** Quality is often expressed in terms of the half-value layer, which is the thickness of a specified material (usually aluminum, copper, or lead) required to decrease the dosage rate of a beam of x-rays at the point of interest to one half of its initial value.

**Beta rays (beta particles)** are particulate ionizing radiation consisting of electrons or positrons traveling at high speed.

**Alpha rays (alpha particles)** are particulate ionizing radiation consisting of helium nuclei traveling at high speed.

**Neutrons** (or neutron rays) are particulate ionizing radiation consisting of neutrons that either possess enough kinetic energy to set in motion, by impact, nuclei of atoms with sufficient velocity to ionize matter; or enter into nuclear reactions that result in the emission of ionizing radiation. The former variety is usually called *fast neutrons* and the latter *thermal neutrons*, with gradations of *epithermal* and *slow neutrons* in between.

**Heavy-particle radiation** is particulate ionizing radiation consisting of atomic nuclei of any mass traveling at high speed (protons, deuterons, helium nuclei, etc.). Alpha rays constitute a special kind of heavy-particle radiation.

**Specific ionization.** When a high-speed charged particle traverses matter, ions are produced along its path. The number of ion pairs per unit length of path is taken to represent the specific ionization of the particle at a given point in its trajectory or "track." In general, ionizing particles with different charges and of different energies may be present in the region of interest, and wide differences in specific ionization may occur. Because the biological effectiveness of an absorbed dose of radiation (see below) depends on the specific ionization, ideally one should know the specific-ionization spectrum of the dose in the locus of interest. This is not feasible at the present time and therefore in practice estimated average values are used.

The number of ion pairs per unit length of track is generally determined in air. In radiobiology, however, one is interested in the transfer of energy to tissues, which includes the energy required to produce ions and the energy imparted to other atoms and molecules that are not ionized but become "excited." It is, therefore, more appropriate to speak of "linear energy transfer per unit length" (LET, according to R. E. Zirkle) than specific ionization. Since in practice values of LET are generally derived from the specific ionization in air, the distinction between the two is essentially a formal one in the present state of the art.

**Dose.** In radiology a *dose* of ionizing radiation is a quantity of radiation. In this connection the term "quantity" represents the magnitude of the dose and may be expressed in various units. Since the adoption of the roentgen, it has been customary to express the magnitude of a dose of x-rays in roentgens. In recent years there has been an increasing tendency to regard a dose of radiation as the amount of energy absorbed by tissue at the site of interest per unit mass. Also, in physics "quantity of radiation" has always had a very special meaning. To avoid confusion the International Commission on Radiological Units at its Copenhagen meeting in July 1953 recommended that a distinction be made between dose in a general sense and "absorbed dose." A new unit, the "rad," was recommended for the latter.

**Dosage rate.** Dosage rate, or dose rate, is the time rate at which a dose is administered, that is, dose per unit time. When the dose is administered intermittently one may speak of an *average dosage rate*. In the case of generators emitting radiation in pulses, the *instantaneous dosage rate* (during the pulse) may be very high while the average dosage rate may be low. Dosage rates are expressed in roentgens or rads per minute or multiples or submultiples of these units, e.g., milliroentgens per hour (mr/hr).

**Intensity of radiation** is the energy flowing through unit area perpendicular to the beam per unit time. It is expressed in ergs per square centimeter per second or in watts per square centimeter.

**Quantity of radiation** is the time integral of intensity. It is the total energy that has passed through unit area perpendicular to the beam and is expressed in ergs per square centimeter or watt-seconds per square centimeter.

**Absorbed dose** of any ionizing radiation is the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It shall be expressed in "rads."

The rad is the unit of absorbed dose and is 100 ergs/gm. One millirad (1 mrad) is one thousandth of one rad.



The roentgen is the quantity of x- or gamma radiation such that the associated corpuscular emission per 0.001293 gm. of air produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign. *One milliroentgen (1 mr)* is one thousandth of one roentgen.

**The rep.** Heretofore the rep (roentgen-equivalent-physical) has been used extensively for the specification of permissible doses of ionizing radiations other than x-rays or gamma rays. Several definitions of the rep have appeared in the literature but in the sense most widely accepted it is a unit of *absorbed dose* with a magnitude of ergs gm. The difference in magnitude between the rep (93 ergs gm.) and the rad (100 ergs gm.) is negligible in the estimation of permissible doses. Therefore, the adoption of the rad to replace the rep does not necessitate a change in the numerical values of permissible doses stated in reps heretofore.

**The rem.** The rem is the quantity of any ionizing radiation such that the energy imparted to a biological system (cell, tissue, organ, or organism) per gram of living matter by the ionizing particles present in the region of interest has the same biological effectiveness as an absorbed dose of 1 rad of x-radiation with average specific ionization of 100 ion pairs per micron of water in the same region.

**Effects of Atomic Radiations on the Body.\*** GENERAL EFFECTS OF IONIZING RADIATIONS. The effects of atomic particles, x-rays, and gamma rays on the tissues are believed to be fundamentally the same in all cases and are due to the process of ionization. When an electrically charged particle, such as an alpha or beta particle, passes through matter, it will occasionally approach close enough to an atom or molecule to exert an electrical force which is sufficient to remove an electron from the atom or molecule. The residue of the atom or molecule, after the removal of the electron, is a positively charged ion; the separate electron and the ion so formed constitute what is known as an ion pair. The electron which is lost from an atom may be an electron which binds the atoms together to form a molecule or it may be an electron from an orbit at another level. The ejected electron may cause the ejection of electrons from other atoms, but eventually it becomes attached to another atom, which then becomes negative.

Although the x-rays, gamma rays, and neutrons are not charged particles and cannot directly produce ionization, when absorbed they cause the ejection of high speed charged particles which in turn produce ionization.

The ultimate effect of ionization is damage to or death of the cells. According to Glasstone and others (1950), "It is the decomposition of certain molecules in living organisms resulting from the breaking of chemical bonds, which alters the characteristics of vital parts of the cells and causes physiological damage." Characteristic changes appear in the nucleus and to a lesser extent in the cytoplasm. Cell division is retarded and abnormal cell division may occur as a result of damage to the chromosomes. Cells at the beginning stage of mitosis appear to be most sensitive to radiation.

The extent of damage to the cells is related not only to the total energy absorbed over a period of time but varies with the intensity of the energy at any one time and with the frequency of the exposures. With low grade exposures repeated at intervals, the repair processes in the tissues may be able to compensate in part for the damage produced. Hence, greater total doses can be tolerated if they are fractionated than if they are administered at one exposure. However, the effects of repeated small doses of ionizing radiation must be cumulative since experiments on animals showed that exposure of the whole body to repeated, small amounts of radiation shortened the life span of these animals.

\* A comprehensive survey of the subject has been published: *Radiation Biology*, Vol. I, High Energy Radiation (in two parts), Hollaender, A., Editor, New York, McGraw Hill Book Co., Inc., 1954.

The type and severity of damage produced in the body as a result of exposure to ionizing radiations depends on the extent of the tissue exposed and on the particular tissue which absorbs the radiations. The tissues of the body appear to differ greatly in their susceptibility to the effects of penetrating radiation. Based on experience with x-rays, they can be listed in the following order of decreasing sensitivity: (1) lymphoid tissues, including bone marrow, blood lymphocytes, lymph nodes, and Peyer's patches; (2) polymorphonuclear leukocytes; (3) epithelial cells, including gonads and ovaries, salivary glands, skin, and mucous membrane; (4) endothelial cells, including blood vessels and peritoneum; (5) connective tissue cells; (6) muscle cells; (7) nerve cells. The lens of the eye and developing teeth also are very susceptible. The cellular changes which are responsible for the clinical symptoms resulting from ionizing radiation are not clearly understood at the present time, although various theories have been advanced to explain the effects produced.

The locus of damage resulting from ionizing radiation depends on the type of particle or radiation and on whether the radiation is applied externally or arises from radioactive material present in the body. Alpha particles are important only when the alpha emitter has been taken into the body through the respiratory or digestive tract or planted in the tissues. Beta particles can exert an effect by external application on the skin, and they can exert an effect internally on other tissues after absorption of the radioactive materials. A radioactive material when absorbed may have a peculiar affinity for certain tissues of the body and thus exert its effect locally on that particular tissue. X-rays always originate externally but owing to their penetrating power they affect the internal organs as well as the skin. Gamma radiation may originate externally or internally since many radioactive materials liberate gamma rays.

**CLINICAL AND PATHOLOGICAL EFFECTS OF IONIZING RADIATION.** *Acute Systemic Effects.* With massive doses of penetrating radiation to the whole body, such as with x- and gamma rays, death may occur in a few hours or days. In less severe cases, loss of appetite, nausea and vomiting occur within an hour or two. The symptoms then subside for a period which lasts one day to two weeks depending on the dose. After this so-called latent period, the original manifestations of illness reappear accompanied by the following symptoms: diarrhea, fever, bleeding and ulceration of the mucous membranes, fall in blood pressure, increased susceptibility to secondary infections, epilation, amenorrhea, increased capillary fragility and a marked decrease in all cellular elements of the blood, especially the lymphocytes and granulocytes. The relation of these clinical symptoms to the dose and interval of time following the exposure are shown in Table 26-5. The pathological changes include hemorrhages throughout the tissues and degenerative changes, chiefly in lymphoid tissue, bone marrow, testes, mucous membranes of the gastro-intestinal tract, and reticulo-endothelial tissue.

*Chronic Systemic Effects.* Multiple exposures to low-grade doses of ionizing radiations may, if continued over a sufficient length of time, produce serious damage. For whole body irradiation Evans (1951) lists the following possible dangers: (1) leukopenia, (2) anemia, (3) sterility, (4) fetal injury, (5) glandular dysfunction, (6) bone necrosis, (7) leukemia, and (8) tumor induction. Dermatitis and epidermoid carcinoma also occur. Other effects which may result from cumulative small exposures are: (1) reduction of life span, (2) injury to the ovaries, (3) increase in mutation frequency, and (4) production of cataracts by neutrons.



Table 26-5. Summary of clinical symptoms of radiation sickness

TIME AFTER EXPOSURE	LETHAL DOSE (600 r)	MEDIAN LETHAL DOSE (400 r)	MODERATE DOSE (300-100 r)
	Nausea and vomiting after 1-2 hours	Nausea and vomiting after 1-2 hours	
First week	No definite symptoms		
	Diarrhea Vomiting Inflammation of mouth and throat	No definite symptoms	No definite symptoms
Second week	Fever Rapid emaciation Death (Mortality probably 100%)	Beginning epilation	
		Loss of appetite and general malaise	
Third week		Fever	Epilation
		Severe inflammation of mouth and throat	Loss of appetite and general malaise
			Sore throat
Fourth week		Pallor Petechiae, diarrhea, and nosebleeds	Pallor Petechiae
			Diarrhea
		Rapid emaciation Death (Mortality probably 50%)	Moderate emaciation  (Recovery likely unless complicated by poor previous health or superimposed injuries or infections)

From Glasstone, S., Editor, *The Effects of Atomic Weapons*, U. S. Gov't Printing Office, 1950, page 147

*Skin Effects.* Beta particles and low energy (soft) x-rays are responsible for most of the damage to the skin since these radiations are absorbed at the surface of the body. High energy x-rays (i.e., hard x-rays) and gamma rays, penetrate the tissues more readily and hence have less effect on the skin. The skin reactions appear after a latent period of a week or two. The reaction includes erythema, edema, pruritis, blisters, sloughing of the epidermis and ulceration. Healing is usually slow. Delayed effects include hyperkeratoses, atrophy of the skin, sweat glands and sebaceous glands and eventually epidermoid carcinoma.

*Genetic Effects.* Since experiments have shown that irradiation of *Drosophila* and mice lead to an increase in mutations, considerable concern has been felt

regarding the possible genetic effects which may result from atomic weapons and the many potential sources of ionizing radiation in use today. No statement concerning the probability of genetic damage from radiation exposure in man can be made on the basis of the experiments on *Drosophila* and mice, and few data on man are available. However, certain general principles as reported by the Office of The Surgeon General (1948) should be considered. The majority of both natural and radiation mutations are recessive; therefore, the probability that they will manifest themselves in a future generation is relatively small. In about 95 per cent of mutations, the offspring die during gestation or soon thereafter. Of the remaining 5 per cent, 95 per cent are deleterious, and of these, 96 per cent pertain to other than sex chromosomes. In the studies which have been made to determine if the atomic bombings in Japan produced genetic effects little of a deleterious nature has been found to date.

**Cancer.** Ionizing radiations appear to be more or less universally carcinogenic. Experiments have shown that ionizing radiations can induce leukemia, malignant lymphoma, and tumors of the ovaries, lungs, mammary glands, skin and other organs in animals. Abundant evidence also exists to prove that ionizing radiations may produce malignant tumors in human tissues which absorb the radiation. Many of the early radiologists developed cutaneous carcinomas before the dangers of such radiations were recognized. A number of cases of leukemia also have been reported in radiologists and radiation workers. Osteogenic sarcomas have resulted from absorption of radioactive materials by luminous dial painters. During World War I, a number of girls painted dials with material containing radium salts and mesothorium. It is believed that these girls absorbed the radioactive materials chiefly through the mouth since they frequently pointed the paint brushes with their lips. They were also exposed to the dust of this material. Whether the agent responsible for the osteogenic sarcomas was radium or mesothorium is not known. A high rate of lung cancer has been reported among the workers in the Schneeberg and Joachimsthal mines in central Europe. These mines contain radioactive materials. Although the lung cancers have been attributed to the inhalation of radon or possibly radioactive dust, the exact agent responsible for the lung cancers has not been definitely determined.

A considerable latent period occurs between the irradiation and the development of the cancer. Cancers may be induced by a single intense exposure or by repeated exposures.

**Maximal Permissible Exposure to Atomic Particles and Ionizing Radiations.\*** No radiation level higher than the natural environmental conditions in which man has evolved can be regarded to be absolutely safe. Hence exposure to radiation should be kept at the lowest practicable level in all cases. In setting maximum permissible doses, the radiation authorities have selected levels which, in the light of present knowledge, are not expected to cause appreciable bodily injury to persons during their lifetime. The maximal permissible doses for external sources of ionizing radiations which have been tentatively adopted and published by the National Bureau of Standards (Handbook 59, Sept. 1954) are as follows:

\* Quoted chiefly from National Bureau of Standards, Handbook 59, September 1954, and Handbook 52, March 1953.



## LONG-TERM EXPOSURE

**Rule I. Ionizing Radiation of Any Type or Types.** For adults under 45 years of age whose entire body, or major portion thereof, is exposed to ionizing radiation from external sources for an indefinite period of years, the maximum permissible total weekly doses shall be 300 mrems in the blood-forming organs, the gonads, and the lenses of the eyes; 600 mrems in the skin; and the respective values of the weekly doses in millirems in all other organs and tissues of the body according to the basic permissible dose distribution. For persons 45 years of age or older similarly exposed, the corresponding maximum permissible total weekly doses shall be double the above stated values, provided that the portion of the weekly dose in the lenses of the eyes contributed by radiation of high specific ionization does not exceed 300 mrems.

**Rule II. X-rays (Roentgen Rays, Gamma Rays) with Photon Energy Less Than 3 Mev.** For adults under 45 years of age whose entire body, or major portion thereof, is exposed solely to X-rays with photon energies less than 3 Mev from external sources for an indefinite period of years; the maximum permissible total weekly dose shall be 300 mr measured in air at the point of highest weekly dose in the region occupied by the person, provided that the actual total weekly dose in the gonads does not exceed 300 mrad. For persons 45 years of age or older similarly exposed, the corresponding maximum permissible total weekly doses shall be double the above stated values, provided that the actual total weekly dose in the lenses of the eyes does not exceed 600 mrad.

**Rule III. Radiation of Very Low Penetrating Power (Half-value Layer Less Than 1 mm. of Soft Tissue).** For adults of any age whose entire body, or major portion thereof, is exposed to ionizing radiation of very low penetrating power from external sources for an indefinite period of years; the maximum permissible total weekly dose in the skin shall be 1,500 mrems, provided that the total weekly dose in the lenses of the eyes does not exceed 300 mrems.

**Rule IV-A. Local Exposure to the Hands and Forearms to Any Ionizing Radiation.** For adults of any age whose hands and forearms are exposed to ionizing radiation from external sources for an indefinite period of years; the maximum permissible total weekly dose shall be 1,500 mrems in the skin, provided the respective weekly doses in millirems in all other tissues of the hands and forearms are not in excess of those that would result from exposure to ordinary X-rays at a weekly dose of 1,500 mr in the skin.

**Rule IV-AX. Local Exposure of the Hands and Forearms to X-rays (Roentgen Rays, Gamma Rays) of Any Photon Energy.** For adults of any age whose hands and forearms are exposed solely to X-rays from external sources for an indefinite period of years, the maximum permissible total weekly dose shall be 1,500 mr in the skin.

**Rule IV-B. Local Exposure of the Feet and Ankles to Any Ionizing Radiation.** For adults of any age whose feet and ankles are exposed to ionizing radiation from external sources for an indefinite period of years; the maximum permissible total weekly dose shall be 1,500 mrems in the skin, provided the respective weekly dose in millirems in all other tissues of the feet and ankles are not in excess of those that would result from exposure to ordinary X-rays at a weekly dose of 1,500 mr in the skin.

**Rule IV-BX. Local Exposure of the Feet and Ankles to X-rays (Roentgen Rays, Gamma Rays) of Any Photon Energy.** For adults of any age whose feet and ankles are exposed solely to X-rays from external sources for an indefinite period of years, the maximum permissible total weekly dose shall be 1,500 mr in the skin.

**Rule IV-C. Local Exposure of the Head and Neck to Any Ionizing Radiation.** For adults whose heads and necks are exposed to ionizing radiation from external sources for an indefinite period of years; the maximum permissible total weekly doses shall be 1,500 mrems in the skin and 300 mrems in the lenses of the eyes, provided the respective weekly doses in millirems in all other tissues of the head and neck are not in excess of those that would result from exposure to ordinary X-rays at a weekly dose of 1,500 mr in the skin. For persons 45 years or older the weekly dose in the lenses of the eyes may be 600 mrems, provided the portion contributed by radiation of high specific ionization does not exceed 300 mrems.

**Rule IV-CX. Local Exposure of the Head and Neck to X-rays (Roentgen Rays, Gamma Rays) of Any Photon Energy.** For adults whose heads and necks are exposed solely to X-rays from external sources for an indefinite period of years; the maximum permissible total weekly doses shall be 1,500 mr in the skin and (1) 450 mr in the lenses of the eyes of persons under 45 years of age, (2) 600 mr in the lenses of the eyes of persons 45 years of age or older.

### OCCASIONAL EXPOSURE

**Rule V-A. Accidental or Emergency Exposure to X-rays (Roentgen Rays, Gamma Rays) with Photon Energy Less Than 3 Mev.** Accidental or emergency exposure of the whole body of adults or parts thereof to X-rays with photon energy less than 3 Mev, from external sources, *occurring only once in the lifetime of the person*, under the conditions and in the respective dosages stated below, shall be assumed to have no effect on the radiation tolerance status of that person.

(a) Exposure of the whole body—any adult. Total dose, measured in air: up to 25 r.

(b) Local exposure—any adult. Dose measured in air and additional to whole-body dose: (1) hands and forearms, up to 100 r; (2) feet and ankles, up to 100 r.

**Rule V-B. Planned Emergency Exposure.** Emergency work involving high-level exposure to X-rays with photon energies less than 3 Mev shall be carried out on the basis that the person will not receive doses higher than one-half the respective doses stipulated in Rule V-A. If the doses actually received in the performance of such work do not exceed the respective maximum doses stipulated in Rule V-A, the exposure may be considered to be in the category covered by Rule V-A. Women of reproductive age shall not be subjected to planned emergency exposure.

**Rule V-C. Accidental or Emergency Exposure to Other Types of Ionizing Radiation.** Rules V-A and V-B are applicable to accidental or emergency exposure to ionizing radiation of any type and energy when the tissue doses resulting therefrom in the different organs and tissues of the body (expressed in rems) do not exceed numerically the respective tissue doses in rads resulting from exposure to X-rays with photon energy less than 3 Mev, under the conditions stipulated in Rule V-A; provided, however, that the portions of the respective tissue doses in rems contributed by radiation of high specific ionization do not exceed 50 percent of the total tissue doses.

**Rule VI. Exposure to X-rays for Medical Reasons.** Exposure of any part of the body to X-rays resulting from ordinary medical diagnostic procedures shall be assumed to have no effect on the radiation tolerance status of the person concerned, provided that no contributory accidental or emergency exposure of the order of magnitude specified in Rules V has occurred within the previous 3 months.

According to Morgan (1955), the present basic permissible rate of 0.3 rem per week cannot be tolerated safely over a large fraction of a life span since the critical organs might accumulate an absorbed dose of 1,200 rem, the skin 2,400 rem and the appendages of the body 4,200 rem. Such doses likely would produce harmful effects.

The permissible concentrations for radioactive materials when taken into the body have been tentatively set for radium and a number of radioisotopes. Estimates made in a few fatal cases indicated that the storage of 1.2 micrograms of radium may prove fatal. Hence, the National Committee on Radiation Protection has set 0.1 micrograms of stored radium-226 as the maximum permissible amount of radium in the body. The allowable concentrations of radioisotopes in the body varies with the specific material. The National Bureau of Standards has published (Handbook 52, 1953) a table giving the maximum permissible amounts of the more common isotopes when fixed in the body and the permissible concentrations of these materials in air and water which one may take regularly into the body.



In connection with these standards it should be noted that air and water are naturally radioactive to a certain degree. Radon normally exists in the air in concentrations of about  $10^{-10}$  microcurie per cubic centimeter, although wide variations occur. Due to the presence of natural radioisotopes much of the drinking water has an activity ranging between  $10^{-6}$  and  $10^{-5}$  microcurie per cubic centimeter. In fact, many of the mineral springs in the United States have natural concentrations ranging between  $10^{-6}$  and  $10^{-4}$  microcurie per cubic centimeter of water.

**Types of Exposures to Atomic Particles and Ionizing Radiations.** In the early days, exposure to ionizing radiations occurred only in the use of x-rays and radium in medicine and in a limited number of research activities. Today, radioactive chemical substances and/or equipment which produce ionizing radiations are used extensively in all branches of medicine, in innumerable research projects of many types, and in many industrial processes. Furthermore, the general public may be exposed to atomic radiations through contamination of the air and water by radioactive waste products. Plumbers and other workmen also may come in contact with radioactive waste materials in the repair of buildings where radioactive isotopes have been carelessly discarded. Some of the most serious radiation exposures occur to persons operating x-ray and fluoroscopic equipment in hospitals, doctors' offices and industries. In some instances, salesmen and the public have been exposed to harmful radiations from fluoroscopic shoe fitting machines. Finally, exposure to these radiations may occur in military operations if atomic weapons are employed.

**Prevention of Damage Due to Ionizing Radiation. PROTECTION AGAINST EXTERNAL SOURCES.** Protection against external sources of radiation can be effected by the use of shielding equipment, by increasing the distance between the source and the personnel, and by decreasing the exposure time. Sources of x-rays, gamma rays, neutrons and beta particles should be surrounded by materials which will absorb the radiations. The material used and the thickness required to absorb the radiation varies with the type of radiation. For example, lead will protect against x- and gamma rays, concrete is satisfactory for gamma rays and neutrons, water absorbs neutrons, glass or plastic materials are effective against beta particles. All direct contact with radioactive materials should be avoided. The distance between the source of the radiations and the personnel should be as great as possible. Doubling the distance will reduce the dosage rate to one quarter in the case of point sources of exposure but not in cases where the sources of exposure are more extensive. Equipment and processes which produce harmful radiation should be operated by remote control when possible. All equipment should be designed so that stray radiation does not occur, and all equipment must be kept in good working condition. When some degree of exposure is absolutely necessary, the duration of the exposure should be reduced so that the total radiation exposure does not exceed the permissible limits.

Persons exposed to external radiation should wear monitoring devices which may be either a film badge or a pencil type ionizing chamber. These devices should be read at the end of each exposure period to determine the approximate degree of external radiation.

**PROTECTION AGAINST INTERNAL ABSORPTION.** Radioactive materials may enter the body through the respiratory tract, digestive tract, damaged skin and, under some circumstances, the intact skin. In order to prevent contamination of the air with radioactive materials, all processes which generate dusts or gases should be totally enclosed or supplied with exhaust systems. Proper cleaning and good house-

keeping are of great importance. Protective clothing should be worn and should be decontaminated or discarded at the end of each exposure period. Great care should be taken that the hands, the lips, and other areas of the skin do not become contaminated and that harmful materials are not introduced into the body through food or tobacco. These protective measures are described more fully in Section 6, since the same preventive methods apply to radioactive materials as are necessary for toxic chemical substances. However, the radioactive materials present additional problems since the more dangerous ones or large quantities of less dangerous ones cannot be discharged into the air or streams. Furthermore, radioactivity cannot be destroyed by burning, chemical treatment, or any other known process. The disposal of radioactive waste materials presents a problem which has not been solved as yet. The methods used by the U. S. Atomic Energy Commission (1950) are described as follows: "Gaseous and airborne wastes are controlled by filtration and dilution with air; mildly radioactive liquids by holding them for a time while they decay into nonradioactive forms, and by filtration and dilution with uncontaminated water; more dangerous liquids are concentrated and run into safe storage; miscellaneous contaminated materials are buried; incinerators are being developed." Radioactive waste materials which are used outside of the plants operated by the Atomic Energy Commission should be handled in accordance with the regulations of the Isotope Division of this Commission.

**HEALTH SUPERVISION AND MONITORING.** The health supervision of persons exposed to radiation hazards in the Atomic Energy Plants, insofar as their radiation exposure is concerned, is under the direction of "health physicists." In industries where the radiation hazards are not great, the supervision of radiation exposures is the responsibility of the industrial hygienists who should have special training in health physics. In medical and educational institutions using radioactive isotopes, radiation protection committees or specially trained persons should be designated to supervise the use of radioactive materials.

The duties of the health physicists and industrial hygienists are as follows: (1) to aid in the design of plants and equipment so that protective measures can be incorporated in the planning stage; (2) to make frequent radiation surveys of all areas and equipment where radiation exposures may exist; (3) to provide individual monitoring meters to all persons exposed to external radiation hazards and to calculate from these the extent of exposure; (4) to make analyses of the expired air, urine and feces, where necessary, to determine the degree of storage of radioactive substances in the body; (5) to recommend the removal from the work area of all persons who show signs of having an excessive external or internal radiation exposure; (6) to inform management and supervisors regarding the radiation hazards; (7) to supervise all personal protective measures; (8) to conduct an educational campaign regarding the safe handling of radioactive materials and safe operation of equipment.

The health physicists are actively engaged in research to determine the effects of radiations, the permissible limits of exposure, the development of protecting measures, the safe disposal of waste products, and the development of radiation detection equipment.

The safe distribution and use of radioactive isotopes is under the direction of the Isotopes Division of the United States Atomic Energy Commission. The chief of the Radioisotopes Branch (Lough, 1951) described the function of this division as follows: "The Isotopes Division determines prior to allocation (of the



isotopes) that a prospective user is equipped by training and experience and with suitable laboratory facilities and instrumentation to use radioisotopes under conditions which will maintain reasonable protection against radiation hazard. This policy markedly minimizes the possibility of improper and careless use of radioisotopes and effectively prevents the development of any widespread radiation hazard in those places where these substances are used. The careful review of applications to determine that conditions are suitable for the use of radioisotopes is effectively supported by the activities of the Advisory Field Service Branch through its consultation on laboratory design and its visits to users at periodic intervals following allocation of radioactive materials. Finally, the dissemination of technical information through the distribution of pamphlets, circulars and reprints serves to enhance the assurance that radioisotopes will be used under safe conditions." The National Bureau of Standards also has published a series of handbooks on standard procedures for handling and disposal of radioactive materials and on methods of measuring radioactivity.

In addition to the environmental control measures, good medical supervision is also necessary. Pre-employment and periodic medical examinations, adequate illness records and their analysis, and other industrial medical procedures are as necessary in the case of radiation workers as in the case of persons exposed to toxic chemicals. These procedures are discussed in Section 6.

The excellent record at the Atomic Energy Plants in regard to radiation illness is a tribute to the work of the health physicists and others who have participated in the health protection program, and, in addition, proves that dangerous radiation exposures can be adequately controlled if a sound preventive program is followed.

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## THE EFFECTS OF HIGH AND LOW BAROMETRIC PRESSURES

During the past century, man has extended his horizon up into the sky and down into the earth. He has developed mechanical equipment which will carry him into the stratosphere, where the air pressure is practically zero, or which will enable him to descend many feet below sea level, where the pressure is very great. But man is physiologically adapted to live only at pressures at or fairly close to, sea level and cannot tolerate these great deviations in pressure. The highest altitude at which man can live is between 17,000 and 18,000 feet. He cannot survive at 25,000 feet when breathing air, and he can work only for brief periods at 300 feet below sea level when breathing air. Thus the real problems of high and low pressures are concerned with man's physiological limitations.

Exposure to low atmospheric pressures occurs whenever a person ascends a high mountain or travels in an airplane, unless the cabin of the airplane is pressurized, i.e., unless the cabin is built so that the air inside can be maintained at atmospheric levels. Exposure to high atmospheric pressures occurs whenever a person descends below sea level through water or water-bearing strata, unless the person is encased in a heavy shell which can withstand the pressure of the water. In all other cases, the person descending below sea level must be supplied with compressed air, i.e., air at a pressure equal to the pressure exerted by the water. Occupations which require exposure to abnormally high pressures include work in compressed air shafts and caissons in the building of tunnels, bridge piers, and mine shafts; and in diving operations in the salvage of ships, in underwater construction, in underwater exploration, and in the collection of pearls, etc.

**The Pressure of the Air and the Effects of Pressure Per Se.** **THE PRESSURE OF THE AIR.** The air at the surface of the earth, i.e., at sea level, exerts a pressure equal to about 760 mm. of mercury, or 14.7 pounds per square inch. This is called the normal atmospheric pressure, or one atmosphere of pressure. At higher altitudes this pressure becomes progressively less, until at 50,000 feet above sea level, the pressure of the air is only about 87 mm. of mercury. On the other hand if an air shaft is cut into the earth, the pressure of the air becomes progressively greater, the greater the depth of the shaft. This increase in pressure is, however, very slight compared to the increase in pressure which exists at the same depth below water or water-bearing strata, because the weight of a column of water is much greater than the weight of a similar column of air. For example, the pressure of the air at a depth of 100 feet below the surface of the earth in an open air shaft would be only a few millimeters greater than that at sea level, whereas under water it would be four times the pressure at sea level. Under water, the

pressure increases at the rate of one atmosphere (760 mm. of mercury, or 14.7 pounds per square inch) for each 33 feet depth below sea level. Thus, at 300 feet below sea level, the pressure is equal to 10 atmospheres or 147 lbs. per square inch.

**THE EFFECTS OF PRESSURE PER SE ON THE BODY.** Although both high and low pressures have marked effects on the human body, these effects are not due to the pressure per se. Living organisms, marine animals, and the tissues of higher animals can withstand the mechanical effects of very high pressures (well over 100 atmospheres). Man can tolerate hydrostatic pressures from low levels up to those which are far greater than would occur in any conceivable circumstance at the present time. This tolerance is due to the fact that the pressure exerted on the surface of the body is transmitted equally to all of the tissues of the body; hence, the pressure relations are the same throughout the body. Even sudden changes in atmospheric pressure exert no harmful mechanical effects except where air is trapped in closed cavities, such as in the middle ear if the Eustachian tube is closed, in the lungs if the glottis is closed, and in the sinuses and digestive tract if blockage occurs. If it is not possible to equalize the pressure in the middle ear and sinuses with the external pressure, pain, hemorrhage, and congestion of the tissues may result from the difference in pressure inside and outside the cavities. The tympanic membrane may be ruptured by a pressure differential of 5 to 10 pounds. In descending from a high altitude, the pressure in the middle ear usually can be brought to the atmospheric level by swallowing, which opens the Eustachian tubes. If these tubes are partially blocked, a forced expiration, with the nose and mouth closed, may equalize the pressure, although this procedure may drive infectious material into the tubes in some cases.

**The Effects of Abnormally High and Low Gas Pressures. THE COMPOSITION AND PRESSURE OF THE GASES IN THE AIR, ALVEOLI AND BLOOD.** In order to understand the effects of high and low atmospheric pressures, it is necessary to review briefly the composition of the air and the pressure exerted by each of the gases in the air. The air is composed of 79 per cent nitrogen, 20.96 per cent oxygen, 0.04 per cent carbon dioxide, and traces of a few other gases. The pressure which is exerted by each gas in the air depends on the atmospheric pressure and the proportion of the gas in the air. Thus, at sea level, where the atmospheric pressure is 760 mm. of mercury, oxygen exerts a partial pressure of 159 mm. ( $760 \times .2096$ ), nitrogen, 600 mm. ( $760 \times .79$ ) and carbon dioxide, 0.3 mm. ( $760 \times .0004$ ). A reduction in the partial pressure of a gas in the air, such as oxygen, is produced either by reducing the total pressure of the air or by reducing the percentage of the gas in the air. At high altitudes, the composition of the air is the same as that at sea level, but, since the total air pressure is less, the partial pressure of each gas is less. Similarly, the partial pressure of a gas in the air is increased either by increasing the pressure of the air, or by increasing the percentage of the gas in the air. For example, when the air is at two atmospheres of pressure, the pressure of the oxygen is twice that at sea level (318 mm.), or equivalent to air containing 42 per cent oxygen at sea level.

The composition of the air in the alveoli is about 80.3 per cent nitrogen, 14.2 per cent oxygen, and 5.5 per cent carbon dioxide. Water vapor is also present, since alveolar air is saturated. At sea level, the partial pressures of these gases



in the alveoli are: nitrogen, 571.8 mm.; oxygen, 101.2 mm.; carbon dioxide, 39.9 mm.; and water vapor, 47.0 mm.

The amount of any gas dissolved in the blood depends on the pressure of the gas in contact with the blood. Also, the amount of oxygen taken up by the hemoglobin varies with the pressure of the oxygen in the alveolar air up to a maximum of about 100 mm. At high altitudes, when the partial pressure in the air falls, the pressure of oxygen in the air and alveoli decreases and the amount of oxygen absorbed by the blood is less. At high pressures, the partial pressures of the gases in the alveoli are increased, more oxygen and nitrogen are dissolved in the blood and in the body tissues. The physiological effects of high and low barometric pressures are the result of these changes in the gases of the blood.

THE EFFECTS OF REDUCING THE PRESSURE OF THE GASES IN THE AIR. The effects of high altitude are attributable to the reduction in the partial pressure of oxygen. At sea level, the partial pressure of oxygen in the air is 159 mm. of mercury, and in the alveoli, 101 mm. of mercury. At 25,000 feet, the pressure of oxygen in the air is less than 60 mm., and in the alveoli, about 30 mm. This partial pressure of oxygen in the alveoli is equivalent to that produced by breathing air containing 7 to 8 per cent of oxygen at sea level. If pure oxygen is breathed at 25,000 feet, the oxygen pressure in the alveoli is about 185 mm., which is more than enough to maintain the normal oxygen level in the blood. At 50,000 feet, the total pressure of the air is only 87 mm., the pressure of oxygen in the air is 18 mm., and in the alveoli approximately zero. Breathing pure oxygen at 50,000 feet is of no value, since the water vapor pressure in the alveoli (47 mm.) plus the partial pressure of carbon dioxide (39 mm.) is equal to 86 mm. or approximately equivalent to the barometric pressure. Thus, it is impossible for man to survive at 50,000 feet even when breathing pure oxygen.

As the pressure of oxygen in the alveolar air falls below 101 mm., the amount of oxygen and thus the tension of oxygen in the blood falls. The body attempts to compensate for the fall in oxygen tension in the blood chiefly by an increase in rate and depth of respiration. This increase in respiration "blows off" the carbon dioxide from the blood, leading to temporary alkalosis. If the person remains at the high altitude, a readjustment of the acid-base balance is produced slowly by excretion of this excess alkali. A second factor which makes it possible for the tissues to secure oxygen at high altitudes is dependent on the inherent shape of the oxyhemoglobin dissociation curve. At low oxygen tensions of the blood, a proportionately larger percentage of hemoglobin is dissociated when passing through the capillaries of the tissues than is liberated at high oxygen tensions of the blood. A third mechanism which plays a role in the adjustment to high altitude is an increase in the concentration of hemoglobin in the blood. A fourth compensatory mechanism at high altitudes is an increase in cardiac output—stroke volume and heart rate—but this adjustment is of lesser importance than the increase in ventilation.

The symptoms which result from ascent to high altitudes vary with rate of ascent, altitude reached, duration of exposure, degree of acclimatization, and personal capacity to adjust. It is possible to ascend in an airplane to greater heights with fewer symptoms if the ascent is rapid and the duration of exposure is short, than to ascend slowly and remain longer. On the other hand, when a person climbs

to high altitudes, it is necessary to climb gradually in order to develop acclimatization. The symptoms of anoxia are well known. The more common signs of anoxia are headache, sleepiness, fatigue, nausea, vomiting, loss of muscular coordination, impaired vision and hearing, psychological changes such as loss of memory and irrational behavior, paralysis, coma and death. Some persons faint without warning at relatively low altitudes. The symptoms which are most commonly found in persons flying to various altitudes, as listed by Armstrong (1943), are shown in Table 27-1.

Table 27-1. General effects of high altitude

ALTITUDE IN FEET	EFFECTS
4,000	Increased depth of respiration. Pulse rate may be increased but later returns to normal. Possible rise in blood pressure.
5,000	Decrease in night vision. Oxygen should be used at night.
10-12,000	Increase in lung ventilation when ascending at 200-1,000 ft. per minute. Generalized body distress in a few and mental anxiety. Changes in blood pressure—some show marked fall. Headache and fatigue if subjects remain 2-4 hours. Oxygen should be used above 10,000.
12,000	Tired, depressed, sleepy or euphoric. Visual acuity less than 50% of normal. Beginning of psychological symptoms. Lung ventilation increased 20-100%.
14,000	Deterioration of voluntary muscular control.
12-15,000	Oxygen should be used if 2 or more hours exposure.
15,000	Oxygen should be used always. Impairment of ocular muscle balance.
16,000	May be fatal to some people. May be loss of sense of touch and pain. Impairment of hearing.
15-18,000	Severe headache, nausea, vomiting, dizziness, mental confusion, muscular weakness and prostration with exposures of 2-6 hours.
20,000	Impairment of vision, loss of consciousness in 15 minutes.
24,000	Severe headache, nausea, vomiting, dizziness, mental confusion, muscular weakness and prostration after 15-20 minutes.
25,000	Coma. Death may occur in 20-30 minutes.
30,000	Loss of consciousness in 1 minute. Decompression sickness may occur.
40,000	Allowable limit with oxygen.
44,000	Absolute limit with oxygen.

In aviation, carbon monoxide also presents a hazard. There is some evidence that any given partial pressure of carbon monoxide produces more acute symptoms at high altitudes than the same partial pressure produces at sea level, i.e., the effects of carbon monoxide are enhanced at high altitudes.

The anoxia produced at the lower barometric pressures may be prevented by breathing oxygen, if the altitude is not too great. All aviation authorities advise that oxygen be available at altitudes above 8,000 feet (or at cabin pressures maintained at comparable levels) and consider the use of oxygen as mandatory at altitudes above 12,000 feet. The Civil Aeronautics Board has certain rules which specify the altitudes at which oxygen must be supplied to pilots and passengers of



commercial planes. The specific requirements vary with the duration of exposure. The military forces also have regulations regarding the use of oxygen in military planes. Because of the marked effect of anoxia on vision, oxygen may be necessary at lower altitudes during night flying. Certain procedures have been shown to increase the altitude to which men can fly without ill effects. These include: the breathing of oxygen before as well as during a flight; the addition of carbon dioxide to the oxygen; voluntary increase in pulmonary ventilation rate and depth during the flight; pressure breathing, i.e., increasing the pressure of the air breathed over the ambient pressure, and previous acclimatization by living at high altitudes for two weeks.

One of the public health problems presented by commercial aviation concerns the possible effects of altitudes on persons with certain diseases. Information on this subject is available from the experience of military authorities in the transportation of battle casualties and of commercial airlines that have carried many ill persons. The general opinion is that persons with the following conditions should not travel by airplane, unless the interior of the cabin is maintained close to the atmospheric level: angina pectoris, if an attack has occurred recently or if attacks are easily induced; recent coronary occlusion; shock; severe anemia; severe asthma; pneumothorax; hypertension, if severe and accompanied by complications; decompensated valvular heart disease; pneumonia; severe bronchitis; overwhelming infections and communicable diseases; and possibly gastro-intestinal ulcers. Diabetic patients should follow their regimes carefully. Except for these severe illnesses, the anoxia encountered in commercial aviation should present no hazard to passengers. Patients with heart disease who can walk and do a moderate amount of work can fly without encountering any greater stress (McFarland, 1953).

**THE EFFECTS OF THE GASES IN THE AIR AT HIGH PRESSURES.** *Effects of Nitrogen at High Partial Pressures.* Although the nitrogen in the air has always been considered as physiologically inert, recent experiments have shown that it exerts a narcotic action when its partial pressure is increased. At air pressures equivalent to three atmospheres of air, the effects of nitrogen begin with a feeling of stimulation. Beyond four atmospheres, the narcotic action becomes more pronounced, and at 10 atmospheres (equivalent to 300 feet below sea level) the impairment of higher mental functions, deterioration of neuromuscular coordination, and alteration of behavior are very marked. Loss of consciousness may occur at pressures in excess of 10 atmospheres. The narcotic effect reaches its maximum after a few minutes of exposure and is enhanced by carbon dioxide. If the nitrogen in the compressed air is replaced by helium or hydrogen no such symptoms occur, and divers can work and think clearly at a depth of 500 feet. Therefore, in order for men to work efficiently, it is recommended that helium and oxygen mixtures be used in place of air for operations at depths greater than 150 feet below sea level. It is essential to substitute helium for nitrogen if work is to be carried on at depths greater than 300 feet.

*The Toxic Effects of Oxygen at High Partial Pressures.* Air containing 60 to 70 per cent oxygen can be breathed indefinitely. However, when pure oxygen is breathed at sea level (equivalent to the pressure of oxygen in air at five atmospheres) pulmonary irritation with edema and, possibly consolidation of the lungs results. The limit of endurance to this pressure of oxygen varies from 7 to 17

hours, or possibly somewhat longer, according to some reports. Other symptoms such as slowing of the pulse, pallor and impaired neuromuscular coordination also have been reported. At higher pressures, oxygen exerts a toxic effect on the body. Three atmospheres of pure oxygen or 15 atmospheres of air can be tolerated for only about three hours. This pressure is equivalent to the partial pressure of oxygen in air at a depth of 500 feet below sea level. When the pressure of oxygen is equal to three atmospheres, sufficient oxygen exists in physical solution in the blood to supply the tissues of the body without any dissociation of the oxy-hemoglobin of the blood. Four atmospheres of pure oxygen can be tolerated for only 30 minutes, as convulsions begin after 45 minutes of exposure. At seven atmospheres convulsions occur without warning after about five minutes. Death may result if the pressure is not lowered rapidly, but recovery is rapid if the oxygen pressure is reduced. Experiments have shown that dogs, which were repeatedly exposed to oxygen pressures sufficient to cause convulsions, exhibited no harmful effects and even developed a certain degree of tolerance to these exposures. The explanation of the toxic effect of oxygen is not clear; it may be due in part to disturbance in the normal carriage of carbon dioxide by the blood and disruption of enzyme activity leading to tissue acidity (Bean, 1945).

*The Effects of Carbon Dioxide at High Partial Pressures.* Carbon dioxide exerts no serious physiological effects at sea level until the concentration increases to about 3 per cent, when stimulation of respiration is sufficient to cause hyperpnea. The inhalation of air containing between 6 and 7 per cent carbon dioxide for short periods causes little mental impairment or deterioration of manual skill, but is distressing since marked dyspnea results. At concentrations above 10 per cent, depression of the central nervous system and heart occurs; respiration becomes slower and more shallow; the heart beat is slow and weak; loss of movement and reflexes follows; and coma results. Death occurs at concentrations of about 20 per cent or higher as a result of the cessation of respiration. The effects of carbon dioxide are attributed to the interference with the transportation of oxygen, the depression of tissue oxidation, and the increase in acidity.

When the air pressure is increased, the partial pressure of the carbon dioxide is increased proportionally, so that the effects of any concentration are equal to the effects of a higher concentration at sea level. Furthermore, some authorities claim that equivalent partial pressures exert more harmful effects in compressed air than at sea level. Case and Haldane (1941) recommend that the concentration of carbon dioxide in compressed air should be kept below a partial pressure equivalent to 3 per cent of carbon dioxide at sea level, while Behnke (1940) suggests .5 per cent as the upper allowable limit.

When air is compressed, not only are the partial pressures of the gases normally present in the air increased, but also the pressure of any contaminating gas, such as carbon monoxide, would be increased likewise and would consequently exert a greater physiological effect than at sea level.

*The Effects of Sudden Decrease in Pressures—Decompression.* When a person, who has been exposed to air under higher pressure, is decompressed (i.e., brought back to normal pressure) too rapidly, or when a person ascends rapidly from sea level to a high altitude, certain characteristic symptoms may develop. In the case of underwater work at high pressure, these symptoms usually appear within the



first few hours following the decompression but may not develop for 12 hours or longer. The most frequent symptom is severe pain in the muscles and joints of the arms and legs which is commonly called "bends." Itching and rash of the skin, vertigo, nausea, vomiting, epigastric pain, fatigue, dyspnea (usually spoken of as "chokes") and shock may occur. In some cases, central nervous system symptoms, such as paralysis of the skeletal muscles or bladder are apparent. In others, symptoms of cardiac failure or pulmonary emboli are evident. Death may occur rapidly or may follow secondary complications. Aseptic necrosis of the bone is reported to follow much later in some cases.

The symptoms of compressed-air illness are due to the presence of nitrogen bubbles within the blood vessels. The nitrogen bubbles are formed because the excess nitrogen, taken up by the tissues and the blood while the partial pressure of the nitrogen was high, cannot be eliminated from the body if the pressure is lowered rapidly. This excess nitrogen can no longer be held in physical solution at the lower pressures and nitrogen bubbles are formed. This reaction is similar to the production of bubbles when a bottle of charged water is opened. The excess oxygen, which is absorbed at the high pressures, is held by the tissues and does not form bubbles, but carbon dioxide contributes somewhat to the bubble formation. As the air pressure is lowered the bubbles expand in size and aggregate, forming gas emboli which obstruct the flow of blood and lead to anemia of the tissues. The nitrogen bubbles are all intravascular except in the fat tissue where they may occur extravascularly.

The location and size of the bubbles depend on the relative solubility of nitrogen in the various tissues, on the duration of the exposure, and on the circulation. Nitrogen is about five times as soluble in fat as in the body fluids, hence more nitrogen can be held by lipoid tissues, such as the nervous system and bone marrow. The duration of the exposure is important because the longer the exposure up to the saturation point, the greater is the quantity of nitrogen taken up by the tissues. Tissues with an adequate circulation absorb and eliminate nitrogen rapidly, but those tissues with a poor circulation and few anastomoses absorb and eliminate the nitrogen slowly and are most affected by air emboli. The bubbles may be caught in the capillaries of one tissue and later be released into the general circulation, thereby producing delayed symptoms. The symptoms depend on the location of the emboli and may simulate many other diseases, since the emboli occur in various parts of the body.

The most important measure for the prevention of compressed-air illness is a slow rate of decompression. Standard schedules of decompression have been adopted by a number of states. Another preventive measure is the inhalation of pure oxygen in place of air during the later stages of decompression. The value of this treatment lies in the fact that the partial pressure of nitrogen in the inhaled air is reduced to zero and, therefore, the nitrogen can be eliminated from the body fluids much more rapidly. Oxygen can be used only at pressures lower than those equal to a depth of 60 feet because of its toxic effect. Recently, helium has been used in place of nitrogen in the compressed air supplied to men working under high pressures. Helium is much less soluble in fat and body fluids than nitrogen so that the total amount of helium which is absorbed by the body tissues at satara-

tion is only about 40 or 45 per cent of the nitrogen saturation capacity. Furthermore, the rate of diffusion of helium in the body fluids is greater than that of nitrogen, and the time required for the elimination of helium is only about 50 per cent of that required for nitrogen. Helium also diffuses through the skin. Another factor which is of the greatest importance for the prevention of compressed-air illness is the proper selection of personnel. Since fat tissues absorb a large portion of nitrogen when under high pressures, men with excessive amounts of fat tissue should not be employed for such work. The treatment for compressed-air illness consists in immediate recompression in a decompression chamber, as soon as any symptoms appear, followed by very slow decompression.

Nitrogen bubbles or air emboli may also occur when a person ascends rapidly from sea level to an altitude of over 25,000 feet. The mechanism is the same as in the case of rapid decompression from high pressures to atmospheric pressure. However, the condition is much less serious since the total body content of nitrogen at sea level is much lower than that at high pressures. The bubbles are all intravascular and central nervous system damage is not common. Air emboli in aviation may be prevented by breathing oxygen or helium-oxygen mixtures before the flight, thus eliminating the nitrogen from the body. The symptoms can be relieved by descending to a lower altitude, since the nitrogen then goes back into solution.

Explosive decompression, i.e., a drop in pressure from one atmosphere to one-tenth or less of an atmosphere in a fraction of a second may occur if a person is shot out of a pressurized plane at high altitudes, such as 50,000 feet. This rapid change in pressure may be injurious but not necessarily fatal. The chief dangers lie in the anoxia which results from the low oxygen pressure and in the expansion of gases in the body. If the glottis is closed, rupture of the alveolar blood vessels may occur and air may be aspirated into the circulation. The sudden rise in the intrathoracic pressure may interfere with the venous return to the heart. Expansion of the gases in the gastro-intestinal tract may cause hemorrhages. At 60,000 feet oxygen passes from the blood stream into the alveoli. Intravascular bubbles may form but they do not present a major hazard.

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# 28

## NOISE

In recent years the effect of noise has become an important public health and industrial problem because of the increase in number and extent of noisy sources.

Exposure to excessively loud noises occurs in aviation, in military operations and in many different types of industries such as boiler factories, steel mills, textile plants, can factories, ship yards, airplane factories, etc.

**Characteristics of Noise.** Noise is discordant sound which results from non-periodic vibrations of air. The chief characteristics of noise are pitch, quality, and intensity. The pitch is determined by the number of double vibrations (dv) or cycles per second which strike the ear. The quality is contingent on the form of the various sound waves contributing to the noise. The intensity at each pitch depends on the amplitude of the vibrations set up by the vibrating body. The intensity varies inversely as the square of the distance from the source. The loudness, as perceived by the ear, depends on the intensity of the sound reaching the ear and also on the pitch, since the acuity of hearing varies with the pitch. Sound may be intensified by placing the vibrating object in contact with other objects which in turn are then set to vibrating. Sound waves may be reflected from walls and objects, thus contributing to the over-all noise level.

**Units Used in Expressing the Intensity or Pressure of Sound.** The sound level may be expressed either in terms of physical units or in terms of decibels. The latter is more commonly used.

**SOUND INTENSITY AND PRESSURE EXPRESSED IN PHYSICAL UNITS.** Sound intensity is defined as the flux of energy per second and per unit of surface ( $\text{cm}^2$ ) at right angles to the direction of propagation and is expressed in watts per square centimeter; or it is defined as an acoustic pressure in dynes per square centimeter (baryes or bars).

The reference base customarily used in acoustics for energy flux (intensity) is  $10^{-16}$  watts per square centimeter; for sound pressure the reference base is  $2 \times 10^{-4}$  dynes per square centimeter.

**DECIBEL SCALE.** The decibel (db)\* is the unit commonly used to express the intensity or the pressure of sound. It is one-tenth of a bel, a unit named after Alexander Graham Bell. The bel is not an absolute unit but a ratio of the unknown intensity or pressure to the respective reference base given above, i.e.,  $10^{-16}$  watts per square centimeter for intensity and  $2 \times 10^{-4}$  dynes per square centimeter for pressure. In the measurement of sound, the impedances are such that the sound pressure ratio is equal to the square root of the corresponding sound intensity ratio.

\* The symbols "db" and "dv" must not be confused: "db" is the abbreviation for decibels sound intensity, "dv" is the abbreviation for double vibrations per second or pitch.



Because of the wide range of acoustic energy to which the ear responds, the logarithm of the ratio is used instead of an arithmetic scale thus:

$$n(\text{in db}) = 10 \log_{10} \frac{\text{unknown intensity}}{\text{reference intensity}} = 20 \log_{10} \frac{\text{unknown pressure}}{\text{reference pressure}}$$

$(10^{-16} \text{ watts/sq. cm.})$ 
 $(2 \times 10^{-4} \text{ dynes/sq. cm.})$

At a frequency of 1,000 double vibrations per second the normal threshold of hearing is approximately equal to the reference points in the physical units. The significance of the decibel scale can be seen from the following example:

20 db =  $10^{-14}$  watts/sq. cm. = 100 times the reference value

50 db =  $10^{-11}$  watts/sq. cm. = 100,000 times the reference value

80 db =  $10^{-8}$  watts/sq. cm. = 100,000,000 times the reference value

Instruments are now available for measuring the over-all sound level and also for analyzing the pitch of the more important sounds contributing to the noise.

**The Intensity and Pitch of Normal Sounds and Noises.** The average human ear can perceive sound which falls in the pitch range between 15 and 15,000 double vibrations (dv) per second. Some persons can hear sounds of considerably higher pitch. The chief range of speech is usually between 500 and 5,000 dv per second although here again the limits may go up much higher. At frequencies above and below approximately 2,000 cycles per second, a greater intensity of sound is necessary to produce the same sensation of loudness as compared with the 2,000 range. Some idea of the intensity of sound measured in terms of decibels may be obtained from an examination of Table 28-1. Audible sounds above 120 decibels may be felt as well as heard. The range of vibrations below 15 dv per second is called infra-audible, and that above 15,000 or 20,000 ultra-audible. These terms have been adopted by The American Standards Association, although some persons use the terms ultrasonic or supersonic in place of ultra-audible.

**The Effects of Noise.** The effects of sound or noise can be discussed under the following topics: (1) the effect on the ear, which is the most important aspect; (2) the psychological effects; (3) the effects on the body as a whole; and (4) the effects of ultrasonic sound.

**THE EFFECTS OF NOISE ON THE EAR.** Excessive noise may produce a masking effect so that it is impossible to hear normal speech unless it is more intense than the noise. Of much greater importance, however, is the fact that noise can cause both temporary and permanent impairment of hearing. Damage to the ear may result from single short exposures (such as gunfire), from continuous noise, or from repeated impact noise (such as drop hammers or presses). The noise level necessary to produce hearing loss varies with intensity and duration, is greater with high-pitched sounds, and depends on the susceptibility of the individual. When the level of intensity is not too high or the noise not too prolonged, the ear may recover from the temporary hearing loss if sufficient time is allowed. Recovery appears to be very slow and may require a period of days or even up to six months depending on the length of exposure. Exposure to higher levels of intensity for brief periods (such as 145 to 180 db) or to lower levels for longer periods may lead to permanent hearing loss. The loss of hearing occurs usually about one-half

Table 28-1. Noise intensity created by common sources expressed in decibels

	DECIBELS
Jet engine	up to 140
Drop hammers	up to 130
Hammer blows on steel plate	up to 115
Boiler shop	up to 105
Punch press	up to 105
Pneumatic drill 10 ft. away	up to 90
Heavy street traffic	80
Ordinary conversation 3 ft. away	40-60
Vacuum cleaner	50
Average residence	35
Low whisper 3 ft. away	20

octave above the predominant tone of the noise, and in general is above 2,000 and especially at 4,096 cycles per second. The loss of hearing is due to damage in certain areas of the cochlea.

The data are not yet sufficient to determine the specific levels of noise required to produce damage to the ear, but certain tentative levels subject to revision when more data become available have been expressed by a group of authorities\* in this field. Their statement was in part as follows: "it seems probable . . . (1) that most persons exposed for several hours daily to noises at intensity levels above 120 decibels, whatever the "composition" of the noise, will in a matter of months suffer permanent damage to hearing; (2) that for most industrial noises at "overall" levels of 100 to 120 decibels, exposure for several hours daily for a long period of time will cause permanent damage to hearing in a considerable proportion of persons, the proportion being higher the more closely the noise approaches the intensity level of 120 decibels and the more the noise is dominated by high-pitched components; and (3) that the hearing of a few very susceptible persons may be permanently damaged by exposure for many years to certain noises at levels between 90 and 100 decibels." † It is difficult to assess the role of noise in cases of hearing loss because many persons, particularly men, develop progressive hearing loss of a similar nature as they grow older. Infections and other diseases also complicate the picture.

Detonations causing about 160 db may rupture the tympanic membrane but the effect of this rupture on hearing is usually temporary and complete recovery may occur. When the tympanic membrane is ruptured the loss of hearing is over the entire frequency range and is present only in the affected ear.

**PSYCHOLOGICAL EFFECTS OF AUDIBLE NOISE.** The effects of noise on work efficiency and fatigue have been discussed in a number of publications. Because of the many variable factors in such studies, it is difficult to draw any very definite conclusions regarding the psychological effects of noise. Claims have been made that a reduction in the intensity of noise increases efficiency and reduces fatigue, but no sound evidence exists at the present time to support this claim. Sudden unexpected noises are reported to cause a rise in blood pressure and intracranial

\* Report of Consultants on Occupational Loss of Hearing to the Workmen's Compensation Board of the State of New York, December 1953.

† The decibel levels mentioned in this report are based on the standard reference level of 0.002 dynes per sq. cm. This report has been criticized severely by other authorities because no account is taken of the pitch of the noise components.



pressure, a reduction in salivary and gastric secretions and in contractions of the stomach. Such effects undoubtedly reflect emotional reactions.

**THE EFFECTS OF NOISE OR SOUND ON THE BODY AS A WHOLE.** Except for the effect on the ear and possible psychological aspects, sound in the audible range up to 120 db does not appear to produce any injury to man. When men are exposed to intense sounds of about 150 db in the frequency range below 2,000 cycles per second (especially 700 to 1,500 cps), certain reactions may occur (Eldridge and Parrack, 1950). The skull, jaws, thoracic wall, and large muscle groups appear to vibrate. Dizziness, weakness of the knees, unsteady gait, headache, and nausea may occur. If continued for some minutes, fatigue, irritability and a sense of apprehension appear. These symptoms all disappear with the cessation of the noise.

**THE EFFECTS OF ULTRA-AUDIBLE SOUND.** With the development of jet airplane engines, the problem of ultra-audible sound became one of importance to man. Since it had been shown previously that ultrasonic sound transmitted through liquid media caused disruption of bacteria and other micro-organisms, and killed frogs and fish in a few minutes, it was thought that such frequencies might produce harmful effects on man. Early experiments with furred animals supported this belief, since ultra-audible sound at intensities above 150 db transmitted through air were found to be lethal for mice, rats, and guinea pigs. However, it has been proved that the effect of ultrasonic sound on furred animals is due entirely to the fact that such sound is absorbed by the animal and produces sufficient heat to raise the body temperature to the lethal point. This excessive heating effect could not occur in man since less than 0.5 per cent of the energy present in ultrasonic frequencies is absorbed from the air by the human body. Transmission through a liquid medium would, however, present different problems.

**Prevention of Noise Deafness.** Injury due to loud noises in industries may be prevented by: (1) mechanical and engineering measures, (2) personal protective equipment, and (3) proper selection of personnel.

The mechanical and engineering measures are the best methods of preventing hearing loss due to noise. These measures include a reduction of the over-all noise level at the source, reduction in the transmission of the noise through the surrounding structures, such as vibrating bases, reduction of air transmission by enclosures, reduction of the reflection of the noise from the surroundings by sound-absorbing materials, and isolation of the noisy processes. Where more than one source contributes to the over-all noise level, the program for the reduction of noise should be directed to the source causing the loudest noise. For example, a noise at 80 db is 100,000,000 times the threshold level whereas a noise at 60 db is only 1,000,000 times the threshold level. The two noises together give a total sound which is 101,000,000 times the threshold value. It is evident that reduction of the 60 db noise will be of almost no benefit as long as the 80 db noise remains.

Personal protective equipment consists of ear plugs (so-called ear defenders) or ear muffs. Ear plugs made of dry cotton are of little value. Treating the cotton with petrolatum will increase the effectiveness. Commercial ear plugs are also available. The most efficient ear defenders will reduce the noise level between 25 to 35 db for high pitched sounds. Their efficiency for reducing low pitched sounds is much less. Ear defenders are uncomfortable, require careful fitting, and may less

to infections of the ear. Ear muffs also will reduce the intensity of sound. They can be fitted and supervised more adequately and offer less chance of infection than ear plugs. Ear muffs, plus ear plugs, will reduce the noise more than either type alone. All personal protective equipment requires constant supervision and effectiveness depends on the cooperation of the employee. According to Eldridge and Parrack (1950), personal protective devices are of less value at sound intensities above 145 db since "bone conduction of sound to the ear can be expected to be sufficient to produce significant hearing losses."

Since there is a marked variation in the reaction of different individuals to the effects of noise, employees who are less sensitive to noise should be selected for noisy industries. It is believed that persons who show temporary deafness early in the exposure to noise are likely to develop permanent hearing loss if continued in the exposure. On the basis of this theory, it has been suggested that audiometer tests be made before employment and at intervals during the first few weeks of exposure to noise. They should be continued periodically thereafter, the frequency depending on the noise level and the characteristics of the audiogram. Workers showing temporary hearing loss during their early exposures to noise should be transferred to other jobs before any permanent damage occurs. Pre-employment audiometer tests are of utmost value in excluding persons with pre-existing hearing impairments from employment in noisy industries. Periodic audiometer tests protect the worker from further injury and the employer from unjustified compensation claims.

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## ATMOSPHERIC POLLUTION

The problem of atmospheric pollution has commanded the attention of health authorities only during the past few years. Complaints about the pollution of the air by smoke and industrial wastes have been prevalent for many years. However, until recently little action has been taken to prevent such contamination. Smoke abatement ordinances were passed in some cities but, except in a few instances, these regulations were not effective. Public health departments, in general, were not concerned about atmospheric pollution, since this subject was considered an economic rather than a health problem. As a result, most industries discharged their waste materials into the air without regard to the effect on surrounding communities. Private dwellings, public buildings, railroads, and automobiles contributed their share to the general contamination of the air.

The interest of health authorities in the problem of atmospheric pollution was aroused about 1945 or 1947 when the Los Angeles smog situation became acute (Stern and Greenburg, 1951). The dramatic episode at Donora, Pennsylvania, in October, 1948 (Schrenk and others, 1949), however, was the major event which focused the attention of all health officers and, in fact, the entire nation on this problem. Hardly had the newspapers carried the story of Donora across the country, than every health commissioner became concerned for fear that a similar experience might occur in his jurisdiction. As a result, tremendous interest in air pollution has developed among health authorities, industrial managements, and the general public. Epidemiological and laboratory research has been initiated; the scientific and technical literature has become extensive; and laws and ordinances have been passed. Thus, atmospheric pollution suddenly has become a major problem in public health.

**Nature of Atmospheric Contaminants.** Foreign substances, most of which are harmless, are present in the air at all times and at all places. The term atmospheric pollution applies only when an excessive concentration of foreign matter which adversely affects the well-being of the individual or causes damage to property, plant, or animal life exists in the air. Atmospheric contaminants may occur in the form of gases and vapors or as aerosols composed of finely divided solid or liquid particulates which remain suspended in the air. (Definitions of the specific types of contaminants which may exist in the air are given in Chapter 32.)

A number of substances may contribute to the pollution of the air. The materials which, at the present time, are believed to be the most important contaminants are: the sulfur compounds, especially sulfur dioxide, sulfuric acid mist, and, to a lesser extent, hydrogen sulfide; the fluorine compounds, especially hydrogen fluoride; chlorine and hydrogen chloride; carbon monoxide and carbon dioxide; oxides of nitrogen; ammonia; ozone; various hydrocarbons; chlorinated aldehydes

ketones and nitriles; formaldehyde; acrolein; organic peroxides; and many other organic compounds including mixtures, such as soot and tar. Zinc, lead, arsenic, and other metallic dusts and fumes also may occur. The chemical and physical properties of these various substances when present in the air and their reactions with one another in the air are not completely understood. Even the sulfur compounds, which have been studied more extensively than any of the other substances, present a number of unsolved problems. Photochemical reactions, catalytic oxidation, adsorption of gases and vapors on particulate matter, solution of gases in liquid aerosols, condensations, and many other reactions contribute to the complexity of the problem. In addition, the nature of the organic material is often difficult to determine.

The contaminating substances listed above may result from many different types of industrial processes. Large amounts of sulfur dioxide are produced by smelting operations, chemical plants and oil refineries; sulfuric acid mist is produced by acid plants; the fluoride compounds are commonly emitted from aluminum plants, phosphate fertilizer plants, refinery processes, and chemical industries. Pulp mills, sewage disposal plants, stockyards, gas plants, steel mills, and many other types of industries contribute to atmospheric pollution. A large part of the atmospheric pollution originates from the burning of fuels, both solid and liquid. For example, the combustion of coal yields sulfur dioxide, fluorine, carbon monoxide, carbon dioxide, finely divided carbon, fly ash, and various organic compounds, including aldehydes, soot, and tar. Fuels are burned by practically all industries, in every home and public building, and by railroads, boats, and automobiles. Even the burning of trash in private homes produces organic and inorganic compounds which may add to the pollution of the atmosphere.

In addition to the materials which are thrown into the atmosphere by combustion of fuels and industrial processes, there are a number of natural substances which may contaminate the air. The most important of these from a health standpoint are the spores, pollens, and dusts from arid regions. Thus, the atmosphere may contain many varied types of pollutants.

**Meteorology as a Factor in Air Pollution.** EFFECT OF WEATHER IN THE PRODUCTION OF SMOG. The degree of atmospheric pollution is greatly influenced by weather and the complicating effects of topography. According to Willett (1950) the two elements of the weather which play a major role in air pollution are: "(1) precipitation (i.e., rain or snow) by which pollutants may be permanently removed from the atmosphere and (2) air motion, or wind, by which local concentrations of pollutants may be widely dispersed throughout the atmosphere."

Heavy rain is a most effective type of precipitation for removing hygroscopic oxides. Snow is more effective in removing soot and other solid particles. Only falling precipitation (rain and snow) is effective in removing contaminants; smogs have no cleansing effects.

Two types of air motion, horizontal and vertical, play a role in the dispersion of atmospheric contaminants. Turbulent winds which blow horizontally at the ground level can effectively remove pollutants. On the other hand, smooth horizontal air flow, rather than dispersing the pollutants, may carry them along the ground in a narrow band of high concentration to a neighboring community. Vertical wind movement is much more effective than horizontal wind movement for removing atmospheric materials away from human contact and for wide dispersion; first,



because the pollutants are removed immediately away from the ground level, and second, because dispersion increases with the height from the ground, due to the fact that the horizontal wind velocity is greater in the upper atmosphere than at ground level. Vertical winds depend on the gradient between the temperature of the air at the earth's surface and that at higher levels. Under normal conditions the air at the earth's surface is warmer than the air above the surface. Since warm air rises, vertical air motion occurs away from the ground. Under exceptional conditions, the temperature differential may be reversed, that is, the temperature of the air may be greater at the upper levels than at the ground. Under such a condition, which is known as a "temperature inversion," a cold layer of air hangs close to the ground and vertical air motion is suppressed. According to Willett (1950): "This is the only condition which permits the accumulation of atmospheric pollutants to dangerous concentrations. Such layers of cold air form at the ground, and collect in valleys and low-lying places generally, during periods of settled weather, clear skies and light winds, primarily during the colder part of the year and at night, in the absence of solar heating of the ground and lower atmosphere. The central portions of stationary or very slowly moving high pressure areas, with their light winds and absence of cloudiness or precipitation are most favorable to the development of extreme conditions of smog (local industrial pollution). Such stagnant smog conditions are likely to become most extreme in the autumn (October, November) after the sun has lost its summer heat and the nights have become long and cool, but before the stronger winds and rapid weather changes of the winter season have set in." The local accumulation of atmospheric pollutants is further increased by the presence of a heavy smoke layer at the ground, especially if fog is also present. This layer filters out the sunlight and thus prevents the sun's rays from heating the lower layer of air. In deep valleys such smogs may prevent any mixing of the contaminated air with the upper atmosphere for several days. "It was exactly this condition of a stagnant high pressure area, with extremely light winds surface and aloft, and the persistence of smog and relatively low temperatures in the valley for four days in succession which culminated in the Donora incident at the end of October, 1948. . . . An even more lethal smog development occurred in the Meuse Valley, near Liège, Belgium, in December, 1931 [*sic*!], under general conditions of weather and local topography which were almost identical with those at Donora" (Willett, 1950).

**USE OF WEATHER DATA AND SELECTION OF TOPOGRAPHY TO PREVENT SMOG DISASTERS.** In order to prevent disasters such as those which occurred in Donora and Liège, new plants which expect to discharge large quantities of waste materials should be located in areas where the regional weather conditions and the topography of the land are favorable for the removal of atmospheric contamination. Unfavorable types of topography include low areas in deep valleys and inland locations far from extensive water surfaces. In the absence of wind, the cool night air from the higher areas settles down into the valleys and leads to a temperature inversion and a retention of pollutants. The most favorable locations to prevent the accumulation of atmospheric contaminants are on a high elevation or well up on a steeply sloping terrain, and or on locations in close proximity to extensive water surfaces. The water surface allows wind movement without the frictional resistance caused by

rough terrain, and the temperature contrasts between water and land favor local winds.

For industries which are already located, hazardous conditions can be prevented by the use of weather forecasts to determine the approach of an unfavorable smog condition. When such weather conditions are anticipated, operations can be reduced and the discharge of waste materials temporarily suspended. In some cases the regular discharge of waste materials into the atmosphere may be timed to fit weather conditions which favor the rapid dispersal of contaminants.

**Effects of Atmospheric Pollution on Health.** In considering the effects of air pollution on health, several questions must be considered: (1) Can acute exposures cause direct damage to health? (2) Can chronic exposures to low concentrations of air pollutants over prolonged periods affect health? (3) What is the role of pre-existing disease in susceptibility to acute or chronic exposures? and (4) Does exposure to air contaminants lower resistance to other diseases such as infections?

**ACUTE EXPOSURES.** Four acute episodes of illness and death due to atmospheric pollution have been reported and well documented: the Meuse Valley disaster in December 1930; the Donora disaster in October 1948; the Poza Rica accident in November 1950; and the London experience in December 1952. In the Meuse Valley disaster the meteorological conditions over a five-day period favored the accumulation of fog, smoke and industrial wastes from the plants in this narrow valley south of Liège. Sixty-three persons and some cattle died on the fourth and fifth days after only a few hours of illness. The symptoms were those of acute respiratory irritation. Death occurred chiefly among elderly and ill persons, although some illness occurred in healthy adults and children. Autopsies on some of the cattle showed pulmonary edema. The cause of the Meuse Valley disaster was never determined, since no air analyses were performed during the smog period, but the scientists who investigated the conditions after the disaster believed that the irritant gases, especially the sulfur and fluorine gases, were responsible for the illnesses and deaths.

In the Donora episode, the smog lasted four and one-half days. A marked increase in illness began on the third day and 17 deaths occurred on the fourth day. Altogether 20 persons aged 52 to 84 years died, and many others became severely ill. Pre-existing disease of the cardiorespiratory system was present in the majority of the fatal cases. The symptoms of the illness included irritation of the respiratory tract and other mucous membranes. Autopsies of three cases showed edema, hemorrhage, purulent bronchitis, and bronchiolitis. As in the case of the Meuse Valley episode, the exact cause of the illness at Donora was not evident. Studies indicated that no single substance was the responsible factor but that more likely a combination of a number of irritant gases and fumes caused the irritations and deaths.

In the Poza Rica accident, large amounts of hydrogen sulfide escaped from a sulfur recovery plant over a period of 20 minutes. Twenty-two persons died and 20 were hospitalized with symptoms of acute hydrogen sulfide poisoning. A number of animals also died.

In London during the period of December 5 to 8, a peculiarly dense fog occurred. Excess illness became noticeable on the third and fourth day of the fog. Examination of the mortality in London during and following this period indicated that approximately 4,000 deaths could be attributed to the fog. The increase in



deaths paralleled an increase in the concentration of sulfur dioxide and smoke in the atmosphere. The deaths decreased subsequent to the fall in the concentration of these substances. The majority of the excess deaths occurred in infants and elderly persons and was attributable to disorders of the respiratory and circulatory systems. The specific causative agents were not clear. The average concentration of sulfur dioxide in the air, although increased, was not excessively high.

In addition to these acute episodes, there are other incidences which can be cited where illness in groups of persons has resulted from atmospheric pollution. The recent cases of lung damage due to beryllium furnish one of the most significant examples of illness resulting from atmospheric contamination by industrial wastes. Ten cases of beryllium granulomatosis occurred among persons who resided within three quarters of a mile of a plant which discharged beryllium compounds into the atmosphere. As far as could be ascertained, these persons had had no other exposure to beryllium except through the atmosphere. These cases, which are described in Chapter 32, indicate the grave danger of atmospheric pollution by materials which, in minute amounts, are able to cause serious illness in susceptible persons.

The irritating smog which occurs periodically in Los Angeles is another example of atmospheric pollution which affects groups of people. In this instance the outstanding symptoms are irritation of the eyes and some lacrimation. The current theory is that the contaminants which are discharged into the air are not immediately irritating but that complex chemical reactions occur in the air in the presence of sunlight leading to the production of irritating substances. Specifically, these substances are considered to be organic peroxides and other oxidation products, produced by photochemical oxidation of the hydrocarbons in the air, mediated through nitrogen oxides. Ozone also appears to play a role. The contaminants which are oxidized are presumably the unburned hydrocarbons from automobile exhausts, organic compounds from burning of refuse, discharges from petroleum and other industries and products from the combustion of fuels. Although the air pollution in Los Angeles produces marked irritation, epidemiological studies thus far have not revealed any effects on general sickness or mortality.

Atmospheric pollution with naturally occurring contaminants such as pollens cause allergic reactions in many susceptible individuals. Allergic reactions also have resulted from atmospheric contamination by industrial wastes. In one instance, persons who lived a mile away from a plant which crushed castor oil beans exhibited severe allergic reactions to this material.

The examples cited above are almost the only well-known instances where atmospheric pollution has caused specific illness in man. Whether this scarcity of evidence indicates that atmospheric pollution rarely causes severe illness or whether it merely reflects the difficulty of assessing the role of atmospheric pollution as an etiological agent in disease cannot be answered at the present time.

**CHRONIC EXPOSURES.** The specific examples of illness and irritation cited in the preceding paragraphs have resulted either from relatively high concentrations of harmful materials or from low concentrations of especially hazardous materials. In addition to these acute specific reactions, health authorities are concerned about the effects of daily exposures to low levels of contaminants which exist in the air of many cities. Studies in Cincinnati and Donora (Kehoe, 1950) have shown, how-

ever, that the extent of atmospheric pollution in an average community atmosphere under normal weather conditions is far below that which might be expected to cause harmful effects. The data presented in Table 29-1 shows the concentrations of certain chemical substances which were found in the air of Cincinnati and Donora, in comparison with industrial standards. It is evident from this table that the concentrations of chemical substances in the air of these communities is extremely low under normal conditions in comparison with concentrations which are considered safe for the majority of workers in industry.

In order to determine whether the low concentrations of irritating materials which existed at Donora under usual circumstances affected the health of the population, the Public Health Service studied the morbidity and mortality records over several years preceding the disaster. The results indicated that the population of Donora did not have higher morbidity or mortality rates than comparable control

Table 29-1. Comparison of maximum allowable concentrations of certain substances in industrial atmospheres, with concentrations found in certain community atmospheres

Concentrations in parts per million by volume, and in mg. per cu. M.

SUBSTANCE	MAXIMUM ALLOWABLE CONCENTRATION *	CONCENTRATION IN COMMUNITY ATMOSPHERES		
		Cincinnati		Donora
		Rural and residential	Commercial and industrial	
Carbon monoxide	100 p.p.m.	Nil to traces	50.0 p.p.m.†	Nil to traces
Chlorine	1 p.p.m.	0.04 p.p.m.	0.055 p.p.m.	0.04 p.p.m.
Fluorine (as hydro- fluoric acid)	3 p.p.m.	0.003 p.p.m.	0.006 p.p.m.	0.005-0.0075 p.p.m.
Oxides of nitrogen	25 p.p.m.	0.10 p.p.m.	0.10 p.p.m.	0.18-0.40 p.p.m.
Sulfur dioxide	10 p.p.m.	0.15 p.p.m.	0.12 p.p.m.	0.32-0.39 p.p.m.
Cadmium	0.1 mg.			<0.001 mg.
Lead	0.15 mg.	0.0015 mg.	0.0035 mg.	0.02-0.032 mg.
Manganese	6.0 mg.	0.004 mg.	0.004 mg.	
Zinc	15.0 mg.	0.001 mg.	0.003 mg.	0.015-0.77 mg.

\* See Table 32-2, page 1040.

† Actual observations range from traces up to 50 p.p.m., the latter being infrequent and of short duration.

From Kehoe, R. A., Proc. First National Air Pollution Symposium, Pasadena, Calif., 1950, p. 117.

groups. Only 1.5 per cent of the persons in the Donora area had a history of chronic bronchitis as compared with 1.2 per cent which was found for the general population in the National Health Survey.

Studies of industrial workers who have been exposed during the course of their work to the same chemical contaminants as exist in community atmospheres, but in even higher concentrations, have not shown injury to health in the majority of the situations studied. However, in the case of atmospheric pollution a number of substances may be present in the air simultaneously, so that synergistic effects may occur, the physical properties of the contaminants may change allowing greater penetration into the lungs, or even the chemical properties may be altered by reactions in the air. Furthermore, the acute episodes described above indicate that chronic pulmonary and cardiovascular diseases, which probably are not common in industrial workers, increase susceptibility to environmental irritants.



Thus, although the evidence at present indicates that atmospheric contaminants under normal conditions in the average city are below the level where they would be expected to affect health, no definite statement regarding chronic effects can be made until more scientific data and epidemiological studies have been made.

**EFFECTS OF ATMOSPHERIC POLLUTION ON SUSCEPTIBILITY TO RESPIRATORY INFECTIONS.** It has been assumed by many persons that exposures to atmospheric pollutants may predispose to infectious diseases of the respiratory tract, such as colds, bronchitis, pneumonia, and tuberculosis. However, sound evidence to support this view is lacking at the present time. Attempts have been made to obtain data bearing on this problem from three sources: (1) statistical studies relating the morbidity and mortality rates of population groups with the degree of atmospheric pollution in their community, (2) experimentation on animals, and (3) studies of industrial workers exposed in the course of their work to the same materials which are found as contaminants in the atmosphere. Data from all three of these sources are subject to certain limitations. Morbidity and mortality rates are affected by so many variable factors that it is almost impossible to determine the specific role of any one factor, such as atmospheric pollution. Furthermore, in these studies, the character and extent of atmospheric pollution has not been measured with any degree of accuracy. Thus, conclusions based on such studies cannot be accepted without further confirmation. Although much valuable information may be obtained from animal experimentation, care must be taken in applying the results obtained on animals directly to man. Industrial studies have supplied the most reliable data on the effects of atmospheric pollution on susceptibility to respiratory infections, but these have been few in number and, furthermore, the results of such studies may not be directly applicable to atmospheric pollution problems because many more contaminating substances may be present at the same time in atmospheric exposures than are usually present in industrial exposures. The following brief review, taken from a paper by Baetjer (1950), will serve to indicate the type of data which are available at the present time regarding the effects of smoke, irritant gases, and dusts on susceptibility to respiratory infection.

Smoke produced by the burning of coal and other fuels is a contaminant of universal interest which has been the subject of several investigations. One study of autopsies in the Pittsburgh district (Schnurer, 1938) indicated that the incidence of pneumonia, bronchitis and emphysema increased in direct proportion to the degree of pneumoconiosis. It was assumed that the pneumoconiosis was produced by the smoky atmosphere of Pittsburgh. Another similar investigation produced the opposite result, namely, that there was no evidence of a relationship between the high incidence of pneumonia in the Pittsburgh area and the degree of pigment deposited in the lungs, although healing by organization of unresolved pneumonia was consistently higher in all of the more advanced grades of anthracosis (Haythorn and Meller, 1938). Laboratory experiments conducted by Vintner and Baetjer (1951) showed that prolonged exposure to smoke produced by the combustion of bituminous coal did not lower the resistance of rats to Type 1 pneumococci injected intrabronchially, although the smoke contained 10 to 30 p.p.m. of carbon monoxide, 0.8 to 1.6 p.p.m. of sulfur dioxide, and 50 to 100 times the concentration of total solids normally present in the air of cities.

Irritant gases favor the invasion of the respiratory tract by infectious agents where severe damage to the mucosa has occurred. However, there is little evidence that prolonged inhalation of air containing sulfur dioxide, chlorine, nitrous fumes, and other irritant gases in low concentrations lowers resistance to acute infections of the respiratory tract. Kehoe and others (1932) compared the health of 100 workers who had been exposed for some years to concentrations of sulfur dioxide (varying from about 10 to 100 p.p.m.) with that of a control group. The incidence of colds was not significantly different in the two groups, although the duration of the illness was extended in the exposed group. However, a significantly higher incidence of nasopharyngitis, which was considered as arising from the local irritation, was found in the exposed group. Evans (1940) reported that the incidence and the death rate of pneumonia and other pulmonary infections were not higher than normal in men who were constantly exposed in their daily work to low concentrations and occasionally to higher concentrations of hydrofluoric acid, chlorine, hydrochloric acid gas, sulfur dioxide, sulfur trioxide, sulfuric acid fumes, phosgene, and other irritant gases. A study made at the Kaiser Shipyards during World War II indicated that the incidence of pneumonia among their 15,000 welders was not greater than the rate for all workers in these shipyards, although welders are exposed to irritant gases and fumes (Collen and others, 1944).

The effects of irritating gases on susceptibility to tuberculosis have been studied more extensively. According to Gardner (1942), neither acute nor chronic exposure to irritant gases lowers resistance to tuberculosis. The tuberculosis rates in men who were gassed during World War I were no higher than the rates among the Army men who were not gassed. Similarly, animals subjected to war gases or to irritating fumes from welding were no more susceptible to tubercle bacilli than were their controls. Men exposed to irritating gases in industries have not shown a higher rate of tuberculosis than that of comparable control groups. The tuberculosis rate in Donora residents was found to be low.

The data available at the present time indicate that neither acute nor chronic exposure to carbon monoxide lowers resistance of men to respiratory infections. Similarly, experiments have shown that exposure to carbon monoxide does not lower the resistance of animals to either pneumococcal or tuberculous infection.

The data on hard rock or mineral dusts have been contradictory. The dust storms in the Middle West during 1935 were reported to have caused a marked increase in morbidity and mortality from acute infections of the respiratory tract (Brown, 1935). Some studies of industrial workers exposed to high concentrations of mineral dusts have shown normal rates for acute infectious diseases of the respiratory tract, whereas other studies have shown high pneumonia rates. However, in the latter cases, the high pneumonia rates may be attributed to the sudden changes in temperature and chilling rather than to the dust exposure. Exposure of rats to silica, feldspar, and other dusts does not lower their resistance to pneumococcal infections (Baetjer and Vintinner, 1944). Free silica dust ( $\text{SiO}_2$ ) is the only mineral dust which appears to lower the resistance of men and animals to tuberculosis, but exposures capable of producing this effect occur only within industry and do not present a problem in atmospheric pollution.

From this brief review, it is evident that no conclusions can be drawn regarding the effect of atmospheric pollution on susceptibility to respiratory infections. There



is no evidence to indicate that atmospheric pollution plays a major role in susceptibility to such diseases.

**RELATION OF ATMOSPHERIC POLLUTION TO LUNG CANCER.** The rapid rise in the death rate due to lung cancer in recent years has focused considerable attention on the possible role of atmospheric pollutants in the production of this disease. Such substances as nonspecific atmospheric dusts, irritant gases, dust from tarred roads, exhaust fumes from automobiles, soot and tar from burning coal and oil and various waste products from industrial operations have been suggested as possible etiological factors contributing to the increase in the incidence of lung cancer. A number of statistical studies have been made in an effort to determine the role of these factors. However, the same caution must be exercised in accepting the results of statistical studies on atmospheric pollution in relation to cancer as was mentioned above in relation to respiratory infections. In the case of lung cancer, it is even more difficult to determine the role of atmospheric pollution since presumably many years are required for the development of this disease. The statistical studies on the role of environmental factors in lung cancer have been carefully reviewed by Hueper (1942). This author has pointed out the many contradictory and confusing results which have been reported.

Considerable evidence exists to indicate that irritation of the lungs per se by irritant gases, such as the war gases, and irritant dusts, such as free silica, does not predispose to lung cancer. On the other hand, chemical analyses of the air in urban locations and of the exhaust fumes of automobiles have shown the presence of certain specific carcinogenic agents such as benzpyrene. However, no evidence exists at the present time to prove that these materials can produce lung cancer in man and, if so, whether the concentration in the air is sufficient.

Thus, at the present time, it is not possible to determine the role of atmospheric contaminants in lung cancer nor to explain the rise in the incidence of this disease on the basis of atmospheric pollution.

This review of the effects of atmospheric pollution on health indicates that atmospheric pollution exerts a major effect on health only under very unusual circumstances. There are no data at the present time to indicate that the usual concentrations of contaminants in the atmosphere are a major hazard to health.

**Other Effects of Atmospheric Pollution.** Although it is difficult to prove that atmospheric pollution has any significant effect on health, except under very unusual circumstances, the economic effects of atmospheric pollution are very well known. In fact, under normal daily conditions, the economic damage produced by air pollution appears to be the most important aspect of this problem. It has been estimated that the losses due to air pollution in this country amount to about one and one-half billion dollars per year.

Sulfur dioxide, hydrofluoric acid, chlorine, some organic compounds, and other substances may cause spotting and burning of the leaves of plants, destroy seedlings and crops, retard the growth of trees, and exert other harmful effects on vegetation. These atmospheric impurities can affect plants directly, in some cases, or indirectly by pollution of the soil. Sensitive species can tolerate only very low concentrations of sulfur dioxide in the air, about 0.1 to 0.2 p.p.m. These concentrations are far lower than the concentration of 10 p.p.m., which is believed to be safe for man. Areas located at considerable distance from the source of pollution may

be affected. For example, sulfur dioxide emitted from smelting plants may affect vegetation as far as 12 or 15 miles from the plant.

Contamination of the atmosphere with some substances may produce harmful effects on cattle. The fluorides present the greatest danger in this respect. Herds of cattle have been seriously affected or even entirely destroyed by eating foliage contaminated with fluorides discharged from neighboring industries. The disease is manifested by a more or less pronounced cachexia with roughening of the coat, diarrhea, loss of weight, fall in milk production, tremor, and marked abnormalities of the bones which lead to a stiff and laborious gait. Death of the cattle may result.

In addition to these effects on vegetation and cattle, other economic losses result from atmospheric pollution. Sulfur dioxide, sulfuric acid mist, hydrogen chloride, nitrous oxides, and other substances which contribute to the acidity of rain and fog cause corrosion of building materials and metals. Hydrogen sulfide discolors lead paint. The fluorine compounds cause etching of glass windows. Ozone may be a factor in the oxidation and deterioration of rubber goods. Tar and soot adhere to surfaces on which they impinge. Tons of solid materials accumulate on the ground and buildings. In 1936, Pincus and Stern (1937) estimated that the soot fall in New York City amounted to between 150 and 200 tons per square mile per month in industrial areas, to about 50 tons in residential areas, and to between 15 and 35 tons in suburban areas. The cost of the cleaning and repairing necessitated by atmospheric pollution is tremendous.

Atmospheric contaminants also interfere with the amount of sunlight which penetrates to the earth. Some years ago, the United States Public Health Service (Ives, 1933) measured the average loss of daylight due to the atmospheric pollution of cities. This study indicated that under some circumstances, 50 per cent of the ordinary daylight was lost as a result of pollution of the atmosphere. The average loss of daylight was around 15 to 20 per cent. Atmospheric contaminants not only reduce the amount of visible light but also may prevent a large amount of the ultraviolet radiation from reaching the earth. In addition to filtering out the sunlight, aerosols cause scattering of the rays of light and thus interfere with visibility. This scattering of light depends not only on the concentration or number of particles per unit volume of air but also on the particle size and index of refraction of the material. Droplets about 0.5 micron in diameter are most effective in scattering light, whereas larger droplets may absorb light. The reduction in visibility due to the scattering of light rays by aerosols is easily observed when driving an automobile at night in a fog.

A number of atmospheric contaminants such as hydrogen sulfide, the mercaptans, the organic peroxides, and many other organic compounds produce unpleasant odors. These may be very disagreeable and are often the chief cause of annoyance among persons residing in communities where such contaminants are discharged into the atmosphere. As far as is known, offensive odors do not produce any direct damage to health, but they may lead to a loss of appetite or even to nausea.

**Prevention of Atmospheric Pollution.** The prevention of atmospheric pollution is an extremely costly operation. It has been estimated that industries are spending many millions each year to prevent contamination of the air. The cost is so excessive that complete elimination of industrial waste discharge into the air can never



be approached. However, the pollution of the air can be greatly reduced by various types of control measures. The first and most important preventive measure is to avoid the production of waste materials wherever possible by a change in plant process. For example, in the burning of fuels, the output of smoke can be reduced by the use of low volatile fuels and, more important, by improved combustion efficiency. Smokeless domestic stoves and industrial equipment for adequate combustion of fuels are now available. Suppression or removal of waste materials at the source is the second important procedure. Acid gases, and vapors may be removed by scrubbing and absorption; dusts and fumes may be caught by filters, collectors, precipitators, etc.; some organic contaminants can be burned; some materials can be neutralized; and some may be recovered by chemical reactions, such as oxidation. In certain cases, recovery of waste materials has resulted in economic gain to the industry, but for the most part the cost of the operation far exceeds the value of the material recovered. A third procedure to prevent undue accumulation of waste products in the atmosphere is to discharge these products into the air through high stacks. Stacks, if sufficiently high, are satisfactory for the dispersion of gases but not for dusts unless the particle size is excessively small. Increasing the height of discharge stacks and the temperature of the discharged air will create better diffusion of the contaminants in the air. The mass rate of emission from stacks is more important than the concentration of the contaminant in the discharged air. Stack emission should be in accordance with meteorological conditions as noted earlier in this chapter. Atmospheric pollution may be prevented by locating plants where the character of the meteorological conditions and topography are favorable to discharge purposes, as discussed earlier in this chapter.

By these and various other methods it is possible to reduce the concentration of atmospheric pollutants to levels which are not harmful to man, animals or plants, and which will greatly reduce the damage to property.

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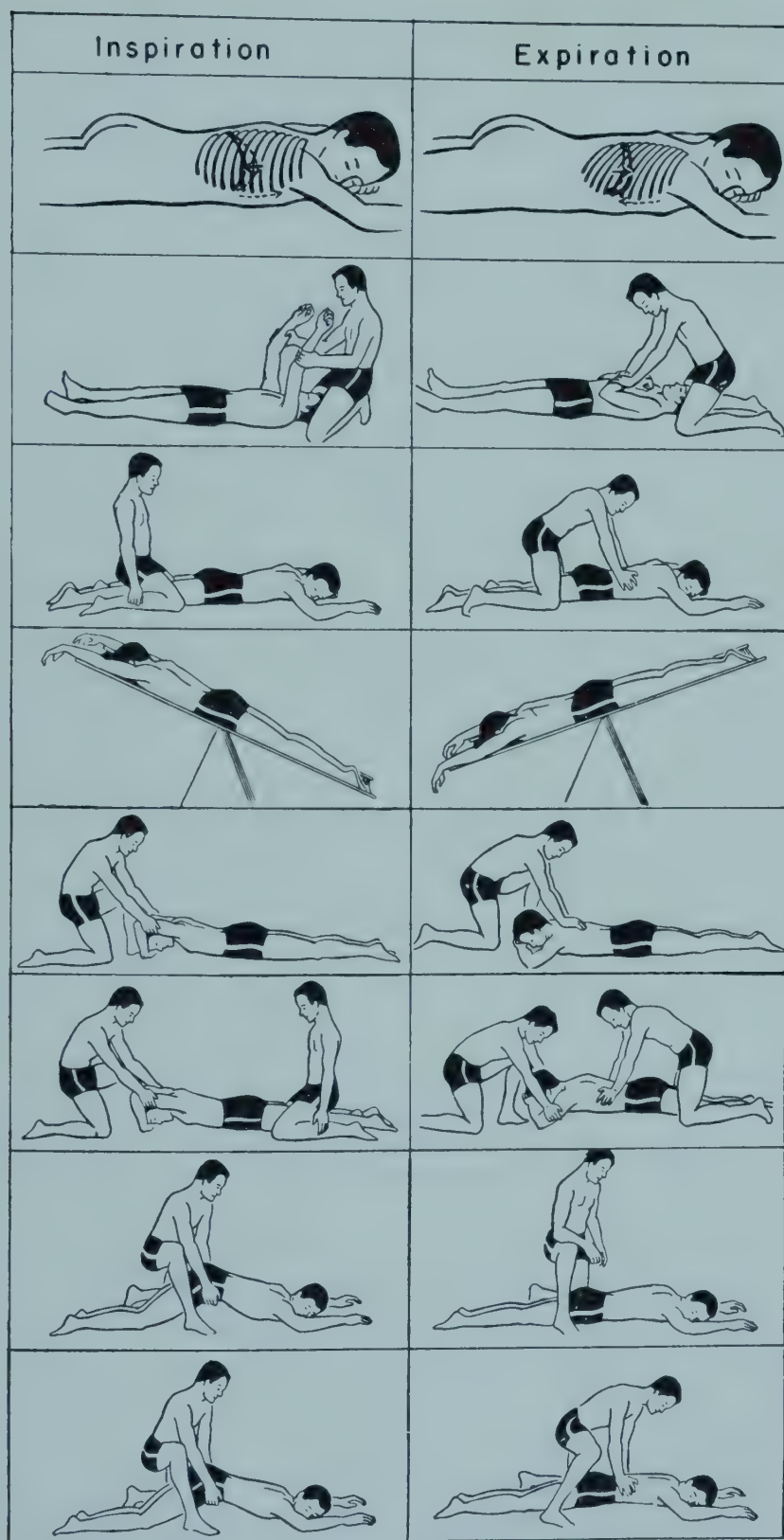
# 30

## RESUSCITATION

Since man can survive only a very few minutes without oxygen it is absolutely essential that artificial respiration be applied immediately whenever normal respiration ceases as a result of drowning, electric shock, the inhalation of carbon monoxide, respiratory paralysis, blockage of the airway, etc. In this chapter, artificial respiration suitable for emergency and field use will be considered. Procedures applicable only to hospital use, such as phrenic nerve stimulation, will not be included.

**General Principles of Respiration.** Before considering the various procedures and equipment which may be used for artificial resuscitation, it is necessary to review certain fundamental principles of respiration and circulation. In normal inspiration, the thoracic cavity is enlarged by contraction of the diaphragm and the other inspiratory muscles; the pressure inside the lungs falls below atmospheric pressure, and air flows into the lungs. The negative pressure in the thorax during inspiration assists in the return of the venous blood to the heart since the pressure on the veins in the abdomen is greater than the pressure on them in the thorax. Under normal conditions, expiration is effected by a passive return of the chest to its original size by relaxation of the muscles. In forced expiration, the contraction of the expiratory and abdominal muscles decrease the size of the chest. During expiration, the pressure in the thorax increases above the atmospheric level and air is forced out of the lungs. The greater pressure on the veins in the thorax than in the abdomen temporarily retards the venous return to the heart during expiration. Since the output of blood from the heart depends on the rate of inflow of blood from the veins, the venous return is a very important factor in maintaining a normal supply of oxygen to the tissues. Thus, in considering the various procedures of artificial resuscitation, their effect on the circulation as well as their ability to supply air to the lungs must be considered. For example, a method which supplies an adequate volume of air to the lungs but which interferes with the circulation may be less desirable than one which provides less oxygen but assists in the return of blood to the heart. Only when sufficient oxygen actually reaches the tissues, can the cells function and the respiration and circulation be restored to their normal condition.

**Methods of Artificial Respiration.** **MANUAL METHODS.** Artificial resuscitation may be administered either by manual or mechanical methods. The various manual methods of artificial respiration which are more or less commonly in use today are shown in Figure 30-1. The Eve method, although not strictly a manual method, is included in this category since it does not require any specially built apparatus. Another manual method of artificial respiration, the pole top method (Kouwen-



From Gordon, A. S., and others, J.A.M.A. 144:1456, 1950.

Fig. 30-1. Manual methods of artificial resuscitation.

1, Normal respiration; 2, Silvester method; 3, Schafer prone pressure method; 4, Eve rock-g method; 5, Nielsen method; 6, combination of Nielsen and Schafer methods; 7, hip-lift method; 8, combination of the hip-lift and Schafer methods.



hoven and others, 1940), was devised for the resuscitation of linesmen suffering electric shock while working at the top of a pole. In the pole top procedure, the rescuer ascends the pole and administers artificial respiration by rhythmic pressure on the abdomen while on the pole, thus avoiding the loss of time in lowering the patient to the ground.

The manual methods of artificial resuscitation fall into four general groups depending on their mode of operation:

1. Methods by which forced expiration is induced by decreasing the size of the thorax. Forced expiration may be produced either by pressure on the thoracic cage (Schafer method) or by an upward movement of the diaphragm by pressure on the abdominal organs (pole top method). The inspiration is passive and depends on the elastic recoil of the thoracic muscles when the pressure is removed, or on the return of the abdominal organs to their original position.

2. Methods by which inspiration is induced by enlarging the size of the thorax. This may be accomplished by a movement of the arms (first stage of the Silvester method) or of the trunk (hip lift method). Expiration results from a return of the arms or trunk to normal posture.

3. Methods by which induced inspiration is combined with forced expiration (Nielsen, Eve, Silvester, hip-lift-Schafer methods).

4. Method by which air is forced into the lungs by blowing into the mouth, thus increasing the pressure at the mouth intermittently (mouth to mouth insufflation).

In all of these methods, except the mouth to mouth method, there may be some slight interference with the venous return during the expiratory phase. It is claimed that the Eve method assists the venous return to a greater extent than any of the other manual methods.

**MECHANICAL METHODS.** The "mechanical" methods of artificial resuscitation include those methods which utilize specially designed equipment. These methods may be classified into two types according to the pressure relationships which they create:

1. Mechanical resuscitators which force air into the lungs by creating a greater pressure at the mouth than exists in the thorax. This principle is used in the bellows type and positive pressure resuscitators where air is blown into the lungs at pressures above atmospheric pressure.

2. Mechanical resuscitators which produce alternating positive and negative pressures at the mouth. By these methods air is forced into the lungs under a pressure greater than atmospheric pressure and is sucked out of the lungs by a pressure at the mouth which is below the atmospheric level. During the positive pressure phase the venous return to the heart is greatly retarded. The cardiac output may be decreased 30 to 40 per cent in some cases. However, this decrease may be compensated for by a more rapid return during the negative pressure phase if the pressure and time for inspiration and expiration are properly regulated.

**COMPARISON OF METHODS.** For many years, the Schafer method of artificial respiration was the official method in the United States. However, recent experimental investigations on humans by Gordon and others (1950) showed that the methods which produce both active inspiration and active expiration, so-called

push-pull methods, result in much better pulmonary ventilation than the methods which produce only either active expiration or active inspiration. The three so-called push-pull methods are the Nielsen method, the Silvester method, and the hip-lift-Schafer method. The last method is difficult to perform, and the supine position of the Silvester method favors obstruction of the airways. Thus the Red Cross, Armed Forces, and other official agencies have adopted the modified Nielsen method as the recommended procedure. The other two methods should be used when the condition of the patient make the Nielsen method unsuitable.

The use of mechanical resuscitators has been the subject of many arguments in past years. Some authorities believed that mechanical resuscitators might damage the capillary walls during the positive phase and might create congestion, pulmonary edema, or atelectasis during the negative phase. However, in recent years mechanical methods of artificial resuscitation have been more widely accepted. Well-controlled experiments have shown that intermittent positive pressure is not dangerous if the pressure relations are properly adjusted, and that larger volumes of air can be introduced into the lungs by mechanical methods than are usually supplied by manual methods. The unfavorable effect of positive pressure resuscitators on the cardiac output can be eliminated if the pressure changes are properly adjusted. Authorities are not yet in agreement regarding the value and possible dangers in the use of negative pressures except that methods producing negative pressures should not be used in cases where pulmonary edema is present.

The desirable features for mechanical resuscitators have been summarized in a report recently published under the auspices of the Council on Physical Medicine of the American Medical Association (Motley and others, 1948). In this report Motley and his associates stated that the ideal type of resuscitator equipment for use on man (producing effective artificial respiration with a minimal disturbance to the circulation) should embody the following characteristics:

"It should be simple and sturdy in construction and operation, small and compact in size . . . The respirator apparatus should stand steam sterilization if expiration occurs through part of the device . . . Expiration should not occur through the flow-sensitive respirators with reversing pistons . . .

"The mask pressure curve should increase gradually during inspiration up to a peak not in excess of approximately 25 cm. of water, and after reversal occurs the pressure drop should decrease rapidly to a final pressure near atmospheric . . . The mean mask pressure during the expiratory period should be as low as possible. [Inspiratory time should not exceed expiratory time. This type of mask pressure curve permits the right side of the heart to compensate during expiration.] There is no apparent advantage of including negative pressure in the cycle.

"Alternating frequency rates should maintain a respiratory rate between 10 and 20 per minute.

"The volumes of pulmonary ventilation provided should be on an average from 10 to 15 liters per minute.

"A regulator line pressure should be provided that takes into account the pressure drop in transmission for the particular type of respirator used and provides peak pressures from 10 to 25 cm. of water (7.4 to 18.4 mm. of mercury).

"The mask most suitable for use in this study has been one having a wide, flatable, thin, soft rubber cuff built over a sponge-type cushion base and detach-



able from a light weight transparent plastic facepiece . . . This type of mask has provided the best leakproof fit and the least dead space."

**Types of Gas to be Supplied.** In addition to discussing the methods of resuscitation, it is necessary to consider the gas—air, oxygen, or oxygen-plus carbon dioxide—which should be administered in artificial resuscitation. Almost all authorities recommend that oxygen when available, rather than air, be used in artificial resuscitation. For many years it was thought that oxygen with 7 or 5 per cent carbon dioxide was more effective in restoring normal respiration than was oxygen or air. In recent years this view has changed. The American Medical Association and Red Cross now recommend that oxygen rather than a mixture of oxygen and carbon dioxide be administered to asphyxiated victims. Oxygen-carbon dioxide mixtures should not be used in any case in which the patient has ceased breathing because under these circumstances oxygen lack, increased blood carbon dioxide, and acidemia are usually present (Dill, 1952). The only situations in which the carbon dioxide mixture may be beneficial are in cases of carbon monoxide poisoning when the patient is still breathing or when hyperventilation precedes cessation of breathing.

An instrument which reduces the pressure of compressed oxygen to atmospheric levels and supplies it to the mouth of a victim through a face mask is usually called an "inhalator." Inhalators must not be confused with mechanical resuscitators since they do not force the oxygen into the lungs under pressure. The inhalators can be used in conjunction with manual methods of artificial respiration or with manually operated mechanical instruments. Oxygen is always supplied with the automatic mechanical equipment. Prolonged use of pure oxygen is, however, dangerous.

The important points which should be borne in mind when considering artificial resuscitation were summarized in a joint statement issued by the American Medical Association, Council on Physical Medicine, and the American National Red Cross (1948). The points listed were as follows:

"The air passages must be free from obstruction. The tongue sometimes presses back into the pharynx, shutting off the airway. The first aider should insert two fingers far back into the mouth and press downward and forward on the tongue. Thus the tongue is brought into proper position. If the victim lies prone, the tongue will then remain in this position. If the victim is not prone, it may be necessary to have an assistant hold the tongue in good position with a handkerchief. Fluid or vomitus may also obstruct the passageway somewhat. If the victim is prone such fluid usually flows out quickly while artificial respiration is given. However it may be advisable to wipe out the mouth, reaching far back with a handkerchief.

"These measures of bringing the tongue forward and of removing other obstruction should be accomplished at once. If only one first aider is present, he should execute these measures between compression, starting after the first one.

"If an accepted resuscitator is at hand, it may be substituted for manual artificial respiration with assurance that sufficient ventilation will occur. Manual artificial respiration, however, is all-important while the rescuer awaits a resuscitator. Use of the manual method should continue while the resuscitator is being adjusted, so that the victim's lungs constantly receive air.

"If a person has not been breathing for five to ten minutes, the chance of su-

vival is slight, even if the most efficient inhalators or resuscitators are used. Nevertheless, an attempt at resuscitation should be made when the slightest chance for recovery exists. Artificial respiration should never be stopped when a pulse or heart beat can be felt. Recovery of normal breathing may be long delayed, especially in cases of electric shock. Most patients recover within about one-half hour, but some have been resuscitated after several hours of artificial respiration."

The most important thing to remember in patients who have ceased to breathe is to start artificial resuscitation immediately. Lapse of a few minutes may mean the difference between recovery and death.

An excellent review of the many complicated factors and unsolved problems in artificial respiration has been published by Whittenberger (1955).

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# Section Six

## INDUSTRIAL HEALTH, DISEASES OF OCCUPATION

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### 31

#### INTRODUCTION

##### SCOPE AND MODERN CONCEPTS OF INDUSTRIAL HEALTH

Industrial health has become an increasingly important field during recent years. It has advanced not only as a result of the general development of public health and preventive medicine, of which it is a part, but also because of recent social trends which emphasize the rights of the working man and his importance to industry. Furthermore, because of the need for maximum production during wartime, tremendous impetus was given to the industrial health movement by both World Wars I and II.

Industrial health, according to the broadest concept, is concerned with all factors which influence the health of people at work. It is, in reality, preventive medicine and hygiene as applied to the working people, including not only persons who are employed in factories, but also farmers, miners, storekeepers, clerks, professional persons, and all others who are gainfully employed in any type of occupation. The objectives of industrial hygiene are twofold: (1) to determine if the working environment or any other conditions of work are harmful to the health of the workers and to prevent these harmful effects, and (2) to promote the maximum health and well-being of people at work. Thus industrial hygiene has both a preventive phase and a positive or constructive phase.

**Preventive Phase of Industrial Health.** On the preventive side, industrial health is concerned with occupational diseases due to all types of harmful chemical substances such as lead, benzol, or silica. Of equal concern are the physiological effects and diseases resulting from the physical factors of the industrial atmosphere such as the temperature of the air or radiant energy. The abnormal stresses of the work itself, due to posture, repeated motion, or improper work methods, also fall within the scope of industrial health. In addition to the specific occupational diseases, industrial health is concerned also with the effects of the working environment and conditions of work on comfort and ability to work, on degenerative diseases, and on resistance to infectious diseases.

In addition to the principal phases of industrial health, as outlined in the preceding paragraph, certain other preventive activities fall into this field. These include cooperation in other health programs for the prevention of industrial infections such as anthrax, and other communicable diseases which may be spread

through the working environment. The study and control of atmospheric pollution is another phase of preventive industrial health. This subject falls within the scope of industrial health because a large part of the foreign substances which contaminate the outdoor atmosphere are waste products from industrial operations and because their control is the responsibility of industry. The prevention of industrial accidents, although not usually the responsibility of industrial health personnel, requires the close cooperation between industrial health and safety programs.

The relation of industrial health work to nonoccupational diseases also must be mentioned. Industrial health programs within industry can contribute greatly to the prevention of nonoccupational diseases through the medical examinations of industrial workers and analyses of medical records. Industrial health personnel, both in private industry and in government agencies, serve as a means of contact whereby general public health programs can reach large groups of adult workers.

**Constructive Phase of Industrial Health.** A complete industrial health program is concerned not only with the prevention of diseases and stresses resulting from the occupation or the working environment, as outlined in the preceding discussion, but it also has as its objective the promotion of maximum health and well-being of people at work. This aspect of industrial health, which involves cooperation with many other special fields, includes the following: the determination of the optimum conditions of work, such as lighting or ventilation; the design of machinery and processes which will place a minimum of stress on the body; the determination of the best types of work for persons of different ages and different physical and mental capacities; the rehabilitation of handicapped persons; the promotion of good human relations and mental hygiene in industry; and other phases.

Like any other scientific and technical work, advances in industrial health depend on research studies. Thus, biological, chemical, medical, and engineering research form an important phase of industrial health. The toxicological effects of chemical substances, the effects of extremes of temperature, noise and radiant energy, and the physiological reactions to work are examples of biological investigations in this field. Studies in the basic principles for the removal of dusts and gases and in the design of machines and processes to fit the workers are types of engineering research. The development of chemical methods for analyzing the contaminating substances in air and chemical studies on biological materials are subjects for investigation by the chemists. These and many other research studies are a fundamental part of industrial health.

It is obvious from the facts just outlined that an industrial health program, in the broadest sense, depends on cooperative activities in many different fields and requires the participation of persons trained in many different disciplines: engineering, chemistry, medicine, physiology, toxicology, physics, and others. A constructive industrial health program is not the work of any one group but the combined effort of many groups working together.

In this section of the book, only the functions which are the direct responsibility of persons engaged in industrial health work will be included.



THE INDUSTRIAL POPULATION

Before discussing the various aspects of industrial health, it is necessary to become familiar with the extent and distribution of the working population in this country. The total number of employed persons in the United States has been increasing steadily throughout the years. This trend from 1880 to 1954 is shown by decades in Figure 31-1. The maximum number of employed males in any

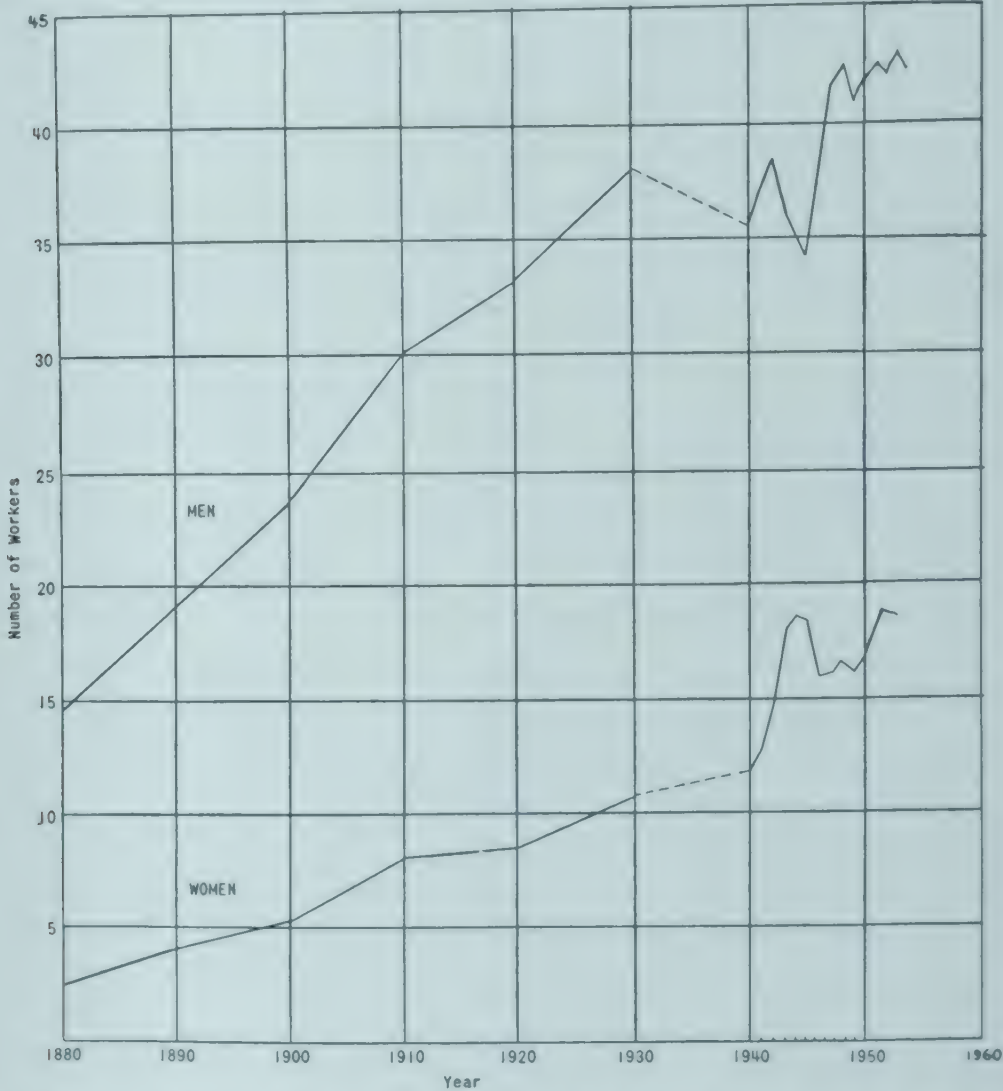


Fig. 31-1. Number of gainfully employed persons in the United States, 1880 to 1954 (1880 to 1940, total labor force; 1940 to 1954, employed labor force). In order to show the recent trends, the numbers are plotted for each year separately between 1940-1954.

year up to the present time was approximately 43 million, and of employed females was almost 19 million.

The distribution of this employed population according to broad occupational and industry groups is also of interest. The number and per cent of gainfully employed persons in the various major occupational groups for the year 1954 are given in Table 31-1. The only recent data giving the distribution of the population according to industrial groups is for the month of April, 1954. These figures are presented in Table 31-2.

Table 31-1. Employed persons, 14 years of age and over, by major occupation group and by sex, for the United States, 1949 (arithmetical means of quarterly estimates)

MAJOR OCCUPATION GROUP	MALES		FEMALES		MALES AND FEMALES	
	Total Number	Per Cent	Total Number	Per Cent	Total Number	Per Cent
Total number employed	42,377,000	100.0	18,861,000	100.0	61,238,000	100.0
Professional and semiprofessional workers	3,433,000	8.1	2,017,000	10.7	5,450,000	8.9
Farmers and farm managers	3,560,000	8.4	114,000	0.6	3,674,000	6.0
Proprietors, managers, officials, except farms	5,085,000	12.0	916,000	4.9	6,001,000	9.8
Clerical and kindred workers	2,797,000	6.6	5,225,000	27.7	8,022,000	13.1
Salesmen and saleswomen	2,415,000	5.7	1,504,000	8.0	3,919,000	6.4
Craftsmen, foremen and kindred workers	8,094,000	19.1	234,000	1.2	8,328,000	13.6
Operatives and kindred workers	9,069,000	21.4	3,607,000	19.1	12,676,000	20.7
Domestic service workers	42,000	0.1	1,734,000	9.2	1,776,000	2.9
Service workers, except domestic	2,585,000	6.1	2,437,000	12.9	5,022,000	8.2
Farm laborers and foremen	1,568,000	3.7	943,000	5.0	2,511,000	4.1
Laborers, except farm and mine	3,729,000	8.8	129,000	0.7	3,858,000	6.3

From Ann. Rept. on Labor Force, 1954. U. S. Bureau Census, Series P-50, #59, 1955.

Table 31-2. Distribution of persons, 14 years of age and over, by major industry group and by sex, for the United States in April, 1949

INDUSTRIAL GROUP	MALES		FEMALES		MALES AND FEMALES	
	Total Number	Per Cent	Total Number	Per Cent	Total Number	Per Cent
Total number persons (14 yrs. and over)	52,681,000		55,592,000		108,273,000	
Total number employed civilians	41,463,000	100.00	16,356,000	100.00	57,819,000	100.00
Agriculture, forestry and fishery	6,849,000	16.52	1,080,000	6.60	7,929,000	13.71
Mining	847,000	2.04	15,000	0.09	862,000	1.49
Construction	3,121,000	7.53	66,000	0.40	3,187,000	5.51
Manufacturing	11,439,000	27.59	3,687,000	22.54	15,126,000	26.16
Transportation, communication and other public utilities	3,945,000	9.51	713,000	4.36	4,658,000	8.06
Wholesale trade	1,765,000	4.26	432,000	2.64	2,197,000	3.80
Retail trade	5,843,000	14.09	3,594,000	21.97	9,437,000	16.32
Finance, insurance and real estate	1,122,000	2.71	785,000	4.80	1,907,000	3.30
Business and repair services	1,104,000	2.66	150,000	0.92	1,254,000	2.17
Personal and domestic services	1,160,000	2.80	2,764,000	16.90	3,924,000	6.79
Amusement, recreation and related services	367,000	0.88	119,000	0.73	486,000	0.84
Professional and related services	2,059,000	4.97	2,275,000	13.91	4,334,000	7.50
Government	1,843,000	4.44	677,000	4.14	2,520,000	4.36

From Current Popu. Rept. Series, U. S. Bureau Census, P-60, #6, p. 26, Feb 1950.



In addition to distribution by industry and occupation groups, several other characteristics of the employed population are of interest. For industrial health purposes, it is important to note the number of persons employed in different sized manufacturing establishments, since large plants can support their own industrial health programs, whereas small plants must depend on group services and government services. In Table 31-3, the number of plants and workers (as of 1947)

Table 31-3. Number of gainfully employed persons in manufacturing plants and number of plants, classified according to size of plant, based on number of employees (1947)

SIZE OF PLANT BASED ON NUMBER OF EMPLOYEES	NUMBER AND PER CENT OF WORKING POPULATION		NUMBER AND PER CENT OF PLANTS	
	Number	Per Cent	Number	Per Cent
Total	14,294,304	100.00	240,881	100.00
1-4	161,007	1.13	70,384	29.22
5-9	310,880	2.17	46,621	19.35
10-19	561,911	3.93	40,646	16.87
20-49	1,243,931	8.70	40,016	16.61
50-99	1,300,719	9.10	18,672	7.75
100-249	2,228,615	15.59	14,323	5.95
250-499	1,932,366	13.52	5,555	2.31
500-999	1,883,464	13.18	2,729	1.13
1000-2499	2,155,727	15.08	1,431	0.59
2500 and over	2,518,684	17.60	504	0.21

From United States Bureau of Census, Manufacturing Establishments Classified by Size, Census of Manufactures-1947. Preliminary Report, Series MC100-6, Aug. 1949.

are listed according to the size of the plants, based on the number of employees. This table shows that approximately 90 per cent of the manufacturing plants employ less than 100 workers but that only 25 per cent of the workers are employed in plants of this size. Fifty per cent of the plants employ less than 10 workers. Almost 18 per cent of the workers are engaged in plants employing 2,500 or more workers. It is evident from these facts that industrial health programs must be organized to fit very different situations.

A knowledge of the number of workers engaged in occupations where potentially harmful working conditions of various types exist is of great importance in industrial health. In order to determine this, the United States Public Health Service, Division of Industrial Hygiene, together with the state industrial health units, made a survey of sample industries in 15 states between 1936 and 1939. These surveys covered 16,803 plants employing 1,487,224 workers engaged in (1) "extraction of minerals," (2) "manufacturing and mechanical industries of all types," (3) "transportation industries," and (4) "personal service." The public health authorities calculated the number and per cent of the workers who were exposed in these sample plants to some potentially harmful conditions. On the assumption that the groups surveyed were representative of the industries throughout the United States, they estimated the total number of workers in the United States who might be considered as exposed to materials and conditions of potential health significance. Their figures are presented in Table 31-4. It should be noted that this table does not give any indication of the number of men exposed to

dangerous concentrations of these materials, but merely the number who work in industries where such materials are used or produced.

Table 31-4. Expected number of workers in selected industry groups in United States exposed to specified materials, 1936-1939

MATERIALS	PER CENT OF WORKERS EXPOSED SURVEY(1)	EXPECTED NUMBER OF WORKERS EXPOSED(2)
Number of workers surveyed (basis for percentages in column 1)		1,487,224
Number of workers in selected industry groups in United States (basis for expected number in column 2)		15,175,301
Organic dusts	18.11	2,748,748
Other metals	14.85	2,254,306
Carbon monoxide	9.75	1,480,062
Petroleum products	9.61	1,458,620
Silicate dust	9.44	1,433,231
Dermatitis producers	9.38	1,422,973
Other gases	9.28	1,408,936
Silica dust	7.53	1,142,503
Nonsilicious dust	6.08	923,114
Lead and its compounds	5.16	783,076
Organic solvents	5.04	765,427
Coal dust, bituminous	4.21	639,442
Alkaline compounds	3.87	587,770
Oils, fats, and waxes	3.85	584,507
Temperature change	2.99	453,408
High humidity	2.84	431,267
Acids, mineral	2.29	347,317
Sulfur dioxide	1.65	250,226
Sulfur and its compounds	1.59	240,938
Salts, inorganic, technical, analytical	1.58	240,088
Paints and enamels	1.52	230,558
Inks	1.32	200,102
Lacquer and varnish	1.28	193,834
Infections	1.27	193,333
Alcohols, ethers, esters	1.14	172,968
Chemicals, organic and inorganic	1.10	167,429
Dyes	1.03	155,835
Hydrogen sulfide	0.89	135,182
Coal tar products	0.86	131,069
Acids, organic	0.85	129,400
Antimony and its compounds	0.65	99,338
Chromium and its compounds	0.54	81,385
Cyanides	0.39	59,335
Aldehydes	0.29	44,388
Halogenated hydrocarbons	0.28	42,218
Asbestos dust	0.23	34,949
Arsenic and its compounds	0.23	34,251
Accelerators	0.22	32,915
Mercury and its compounds	0.22	32,855
Fluorine and its compounds	0.21	32,065
Cadmium	0.20	30,927
Benzene	0.19	28,120
Manganese and its compounds	0.15	23,340
Medicine	0.15	22,475
Chlorine	0.12	18,605
Phosphorus	0.09	14,007
Coal dust, anthracite	0.08	11,473
Hides	0.04	6,586
Aniline and its compounds	0.04	6,434
Amines	0.03	4,659
Selenium and its compounds	0.03	4,113
Radium and radioactive substances	0.01	2,200

From Bloomfield, J. J., and others, A Preliminary Survey of the Industrial Hygiene Problem in the United States, Public Health Bull. #259, FSA, U.S.P.H.S., Washington, D. C., 1940.



## OCCUPATIONAL DISEASES

## GENERAL CONSIDERATIONS

Occupational diseases are usually defined as diseases arising out of, or in the course of, employment. In the strictest sense, this term includes only those diseases which are specific to the occupation, i.e., those in which the etiological agent occurs only in the occupational exposure. However, industrial hygiene is concerned with all types of diseases and impairments to health which are caused or affected by the working environment or by the conditions of work. From this viewpoint, the relation of occupational exposures to diseases, such as the common respiratory infections or circulatory diseases, is of equal importance. In this section, the specific diseases which result directly from industrial exposures and the effects of industrial exposures on susceptibility to infectious diseases will be described.

**Classification.** Occupational diseases can be grouped, according to the causative agents, under four categories:

1. Diseases resulting from exposure to chemical substances such as dusts and gases. The most important of the occupational diseases due to chemical substances are discussed in the succeeding chapters.
2. Diseases resulting from the physical state of the environment such as temperature, radiant energy, and noise. These factors have been discussed in section 5, under environmental medicine.
3. Diseases resulting from the mechanical factors such as pressure, physical strain, and movement. The occupational diseases due to these factors are discussed in Chapter 34.
4. Diseases due to infectious agents such as anthrax, brucellosis, fungus infections. Since these diseases have been discussed in other sections of this book, they will not be considered in this section.

**Incidence.** There are no reliable statistics on the incidence of occupational diseases. Although a number of states have laws requiring the reporting of occupational diseases, these laws are not enforced. Furthermore, many occupational diseases are not recognized because of the lack of characteristic symptoms, the long period of exposure required, the long latent period between the end of exposure and the illness in some cases, and the unfamiliarity of most doctors with the industrial conditions to which their patients are exposed.

Some figures on the incidence of occupational diseases are available from compensation records, but these yield only limited data since occupational disease compensation laws usually cover only those cases causing disabilities of more than

three or seven days' duration or death. However, the United States Public Health Service has collected some statistics on occupational diseases in the various states. The limited data they were able to accumulate are presented in Table 32-1. These

Table 32-1. Incidence of alleged or suspected occupational diseases as reported in 28 states and for Federal employees during a year's period, by nature of disease

NATURE OF DISEASES		TOTAL
All Diseases		43,307
1. Systemic Effects Due To Chemical Agents		2,252
ammonia, 24; anilin, 23; arsenic, 16; benzol or its derivatives, 16; beryllium, 9; carbon bisulfide, 6; carbon monoxide or dioxide, 233; carbon tetrachloride, 32; chlorine, 29; chrome, 154; cyanide, 15; halogenated hydrocarbons, 14; insecticides, 323; lead, 491; mercury, 14; petroleum products, 23; phosphorus, 5; sulfur dioxide, 14; zinc, brass, 84; gases not specified, 202; paint solvents, 33; miscellaneous and not known, 492		
2. Dust Diseases of the Lungs		1,999
asbestos, 21; anthracosilicosis, 233; silicosis,* 1,615; pneumoconiosis, other, and not specified, 130		
3. Respiratory Disorders		667
bronchitis, influenza, pneumonia, 79; respiratory irritations and not specified, 588		
4. Disorders Due To Physical Conditions		4,127
pressure abnormalities, 58; effects of repeated motion, pressure or shock, 3,748; effects of heat, cold, 304; all other,† 17		
5. Infective and Parasitic Diseases		1,148
anthrax, 69; brucellosis, 50; tuberculosis, 811; communicable and not specified, 218		
6. Diseases of the Skin		23,502
7. Miscellaneous Conditions		9,612
allergies (other than skin), 211; cancer, 7; conjunctivitis, 2,034; blisters, abrasions, 567; effects of bites, stings, 1,635; heart disease, 10; neuritis, arthritis, 144; all other, indefinite, not specified, 5,004		

\* Includes 134 cases reported as silicotuberculosis.

† Includes 14 cases of loss of hearing—3 due to radiation.

figures are based on all available published and unpublished data from 28 states and Federal employees over the years 1949 to 1951 (Trasko, 1953). From Table 32-1, it is seen that dermatitis is numerically the leading occupational disease reported, accounting for over one half of the cases. Diseases due to chemical agents and to repeated motion and pressure are next in importance. Although they are numerically less significant than the dermatoses, they are usually more serious.

## OCCUPATIONAL DISEASES RESULTING FROM CHEMICAL EXPOSURES

Practically all occupations involve some chemical exposures. The tailor may be exposed to carbon monoxide from his gas-fired presser; the typist may use an organic solvent for cleaning the typewriter and organic fluids for mimeograph work; the farmer sprays his products with insecticides; the miner is surrounded by coal and possibly silica dust. Similar conditions occur in every other type of employment. Some chemical substances which are encountered in industry have no effect on health. On the other hand, some of them are extremely dangerous and their effects may be manifested in many different ways.



The etiology, symptoms, pathology, and treatment of occupational diseases are discussed in appropriate textbooks and scientific journals which are listed in the bibliography. It is desirable, however, to present here information regarding the relative importance of the more common industrial poisons, their general mode of action and principal effects, their role in susceptibility to other diseases, such as respiratory infections and cancer, and the methods by which their harmful effects may be prevented.

Before reviewing the effects of specific chemical substances, the general characteristics of chemical exposures must be considered.

**Types of Chemical Exposures in Industries.** Chemical materials encountered in industry may occur as liquids, mists, gases or vapors, dusts, fumes, or smoke. Since some of these terms have a special meaning in industrial hygiene work, it is necessary to define them:

**LIQUIDS.** Fluids characterized by the free movement of molecules but without tendency to separate from one another as in the case of gases.

**GASES.** Aeriform fluid having neither independent shape nor volume but tending to expand indefinitely into any volume available.

**VAPORS.** Gaseous materials very near the condensation point or the gaseous form of substances which are normally in solid or liquid state but which vaporize at relatively low temperatures. Vapors tend to diffuse.

**DUSTS.** Finely divided solid particles (0.1 to 150 microns in diameter) formed by the disintegration of solid materials, either organic or inorganic, by such processes as crushing, grinding and abrading. Dusts do not diffuse, they settle according to size and do not usually flocculate in air to any great extent.

**FUMES.** Very small solid particles formed by physicochemical reactions such as condensation of vapors from heated metals and other substances, often accompanied by chemical reactions such as oxidation. Fumes are less than 1 micron in diameter. They flocculate and sometimes coalesce.

**SMOKE.** Liquid or solid particles which are products of incomplete combustion of carbonaceous matter such as coal, wood, oil, gas, or tobacco. Smoke particle sizes range from .001 to 0.3 micron in diameter.

**MISTS OR FOGS.** Droplets formed by condensation of vapors upon suitable nuclei or by breaking up a liquid such as by splashing, foaming or atomizing into a dispersed state.

**SMOG.** A popular term which has recently come into use to describe a combination of smoke and fog in the outdoor atmosphere. This term is also applied to complex mixtures of gases, fine particles of dust and liquid droplets. Smogs are characterized by the general murkiness they impart to the atmosphere.

**Chemical and Physical Properties of the Materials in Relation to Occupational Diseases.** The most important factors which determine whether or not a chemical substance produces damage to health are the chemical nature and physical properties of the material. The rate of absorption, character of the tissue reaction, location of the damage, mechanisms of detoxification and elimination of the substance, etc., all depend on the chemical property of the specific material. For example, the solubility of a material determines the rate of absorption and in some cases the locus of action; thus fat-soluble substances affect some tissues whereas water-soluble substances may affect others. The chemical structure of a material determines its effects on the cell metabolism, its conjugation with other

chemicals, etc. The physical properties are also important. For example, the size of the dust particles affect their penetration in the lungs, their rate of solubility in proportion to the mass, and in some cases, the type of tissue reaction. Thus, fumes, which are composed of very small particles, are usually more dangerous than dusts.

**Locus of Effect of Chemical Substances.** Chemical substances encountered in industry may affect the health of the workers in various ways. They may have a local action directly on the skin, eyes, or upper respiratory tract. They may be inhaled or swallowed and thereby produce damage to the deeper respiratory tract or irritation of the gastric mucosa. They may be absorbed into the blood stream and produce systemic toxic or other harmful effects in one or more of the internal organs. Some of these chemical substances in industries are capable also of causing allergic reactions. These allergic reactions are usually manifest as skin conditions, although allergic respiratory reactions are occasionally produced. Some chemicals may affect the body in such a manner as to alter resistance to infectious diseases or play a role in the development of chronic diseases.

In addition to the specific physiological and toxicological reactions which may result from chemicals, there are two indirect effects which must be mentioned: accidental injury due to the explosive properties of some substances and the psychological effects of disagreeable odors.

**Mode of Entry and Absorption of Chemical Substances into the Body.** Chemical substances in the environment may be absorbed through the respiratory tract, the digestive tract, or the skin. By far, the most important route of entry is through the respiratory tract. Dusts, fumes, gases, vapors, and mists when present in the air are constantly inhaled. Some chemical substances do not penetrate to the deep lung tissue but are absorbed through the mucous membrane of the upper respiratory tract, whereas other substances are absorbed in the lungs. The rate of absorption depends on the solubility of the substance and on the rate of respiration and circulation. Toxic chemicals which are absorbed through the respiratory mucosa enter the systemic circulation and thus reach all tissues of the body before passing through the liver, which is the most important organ for the detoxification of many chemical substances.

On the other hand, chemical substances which are absorbed through the digestive tract may be removed or detoxified by the liver before reaching the circulation. Chemical substances in industrial exposures reach the digestive tract either by swallowing of materials which are precipitated on the upper respiratory tract or by contamination of the mouth through the hands, cigarettes, or food. Much of the material which is swallowed is excreted directly through the feces without being absorbed. The amount which is absorbed through the gut depends on the reaction of the contaminating chemicals with the digestive secretions, with food, with the products of digestion, and other factors.

Absorption through the intact skin is an important mode of entry only for certain compounds. The aromatic nitro and amino compounds such as TNT and picric acid are readily absorbed through the skin. Hydrocyanic acid gas, nitroglycerine, tetraethyl lead, ethylene chlorhydrin, and some other organic chlorinated compounds are other examples. All substances which are soluble in fats may be absorbed through the skin to a certain degree. Almost any substance may be absorbed through damaged skin.



**Individual Tolerance to Chemical Contaminants.** Individual tolerance is an important factor in determining whether a person develops an occupational disease in response to toxic chemicals. It is a universal experience that some workers become ill, whereas others appear to be entirely unaffected by identical exposures. It is sometimes difficult to convince non-medical persons that the occupation is responsible for an illness in one worker when other workers in the same group are not affected. Actually, this is exactly what one would expect in view of the marked variation in physiological functioning, biochemical reactions, and anatomical structure which exist from one individual to another. Even genetically pure strains of animals raised under identical conditions show great differences in tolerance to toxic chemicals. Undoubtedly, nutrition and alcoholism play a major role in individual liability to many occupational diseases. This fact is particularly apparent in the case of organic solvents, such as carbon tetrachloride, which may produce damage to the liver.

**Role of Sex, Race and Age in Tolerance of Chemical Substances.** There have been many statements in the literature that women are more sensitive to occupational poisons than men. This point of view has led to some state laws prohibiting women from working in certain types of chemical exposures. Careful examination of the literature, however, indicates that there is no evidence to support this view. The data on which these statements have been based are contradictory and subject to criticism since the comparisons have been made chiefly between women and men working under different conditions and with different degrees of exposure. The evidence available at present indicates that race is not an important factor in occupational diseases, except possibly in the dermatoses. It is generally stated that young persons are more sensitive to chemical poisons than older persons. However, it is difficult to determine whether there are significant differences within the age groups employed in this country today and, if so, how these differences are due to habits, nutrition, or to other factors rather than to age.

**The Effect of Concentration and Duration of Exposure.** A most important factor in the production of occupational diseases is the degree of exposure, which depends on the concentration of the harmful substance and on the duration of exposure. The effects of harmful chemical exposures increase with an increase in the concentration of the substance and the length of the exposure. However, the effect produced is not a direct function of concentration multiplied by the duration of exposure. For example, if 100 parts of a substance per million parts of air (100 p.p.m.) is a safe exposure for eight hours, it does not follow that 800 p.p.m. is safe for one hour. There are several reasons why this is true. If low concentrations of chemical substances are absorbed, the rate of excretion or detoxification may equal the intake so that no damage results from this material, whereas high doses for shorter periods may lead to retention with harmful results. Furthermore, the type of effect often differs with the concentration.

Exposures to high concentrations may produce an acute reaction which is immediate and severe. On the other hand, daily exposures to low concentrations over many weeks may lead to chronic illness of an entirely different nature. In the latter case, the chemical material itself (such as lead or manganese) may accumulate in the body, or the damage produced by the material, as in the case of benzol or carbon tetrachloride, may be cumulative even though the material does not remain in the body. In some cases, months or even years may elapse before

the end of exposure before the damage is manifest. In the chronic cases, it is often difficult to determine the relation of the occupation to the disease unless the symptoms are characteristic and the occupational exposure is known. The symptoms of most occupational diseases are not specific but are common to many nonoccupational diseases. Thus, the occupational history becomes of major importance in the differential diagnosis of chronic occupational diseases.

**Maximum Allowable Concentrations of Chemical Substances in the Air.** One of the major problems in industrial hygiene is the determination of the maximum concentration of air-borne chemical substances which a worker can tolerate without impairment to his health. Information of this character is necessary not only to protect the health of workers, but to furnish industries and governmental agencies with a basis for evaluating industrial health hazards and for establishing control procedures. Hence, industrial hygienists have attempted to set certain standards. These are known as "Maximum Allowable Concentrations" or "Threshold Limits." These terms are used to indicate the maximum concentration of a chemical substance in the air which is considered safe for daily exposures of eight hours over long periods of time.

Maximum allowable concentrations have been suggested for most of the chemicals commonly found in industry. Individual research workers, governmental institutions, and private agencies have all participated in the effort to define such limits. The Committee on Threshold Limits of the American Conference of Governmental Industrial Hygienists has compiled the most extensive list of these so-called threshold limits, which they revise yearly. This list, with the revisions through April 1955, as adopted by the conference, is given in Table 32-2, pages 1040-1042 (Amer. Conf. of Govern. Ind. Hyg., 1955).

The following excerpts from the 1955 report of this committee should be carefully noted in order to interpret those values correctly.

"Values are given . . . for the maximum average atmospheric concentrations of contaminants to which workers may be exposed for an eight-hour working day without injury to health.

"These values are based on the best available information from industrial experience, from experimental studies, and, when possible, from a combination of the two. They are not fixed values but are reviewed annually by the Committee on Threshold Limits for changes, revisions, or additions as further information becomes available. Threshold limits should be used as guides in the control of health hazards and should not be regarded as fine lines between safe and dangerous concentrations. They represent conditions only within which it is felt that workers may be repeatedly exposed, day after day, without their health being adversely affected. It is felt, at the present time, that workers should not be exposed to a working environment containing any of these substances in excess of the value indicated.

"These values are not intended for use, or for modification for use, in the valuation or control of community air pollution or air pollution nuisances."

In order to use maximum allowable concentrations intelligently, it is necessary to understand the various methods for obtaining such values and their inherent limitations. First, a number of these standards have been based on animal experiments. Since different species and even different strains of the same species vary greatly in their susceptibility to toxic chemicals, it is questionable how far such data are applicable to man. Second, some laboratory experiments have been per-



Table 32-2. Threshold limit value adopted at April 1955 meeting of the American Conference of Governmental Industrial Hygienists

Established Values			
GASES AND VAPORS			
SUBSTANCE	P.P.M.	SUBSTANCE	P.P.M.
Acetaldehyde	200	Heptane ( <i>n</i> -heptane)	500
Acetic acid	10	Hexane ( <i>n</i> -hexane)	500
Acetic anhydride	5	Hexanone (methyl butyl ketone)	100
Acetone	1,000	Hexone (methyl isobutyl ketone)	100
Acrolein	0.5	Hydrogen chloride	5
Acrylonitrile	20	Hydrogen cyanide	10
Ammonia	100	Hydrogen fluoride	3
Amyl acetate	200	Hydrogen selenide	0.05
Amyl alcohol (isoamyl alcohol)	100	Hydrogen sulfide	20
Aniline	5	Iodine	1
Arsine	0.05	Isophorone	25
Benzene (benzol)	35	Mesityl oxide	50
Bromine	1	Methyl acetate	200
Butadiene (1,3-butadiene)	1,000	Methyl alcohol (methanol)	200
Butanone (methyl ethyl ketone)	250	Methyl bromide	20
Butyl acetate ( <i>n</i> -butyl acetate)	200	Methyl cellosolve (methoxy-ethanol)	25
Butyl alcohol ( <i>n</i> -butanol)	100	Methyl cellosolve acetate (ethylene glycol monomethyl ether acetate)	25
Butyl cellosolve (2-butoxyethanol)	200	Methyl chloride	100
Carbon dioxide	5,000	Methylal (dimethoxymethane)	1,000
Carbon disulfide	20	Methyl chloroform (1,1,1-trichloroethane)	500
Carbon monoxide	100	Methylcyclohexane	500
Carbon tetrachloride	25	Methylcyclohexanol	100
Cellosolve (2-ethoxyethanol)	200	Methylcyclohexanone	100
Cellosolve acetate (hydroxyethyl acetate)	100	Methyl formate	100
Chlorine	1	Methylene chloride (dichloromethane)	500
Chlorobenzene (monochlorobenzene)	75	Naphtha (coal tar)	200
Chloroform (trichloromethane)	100	Naphtha (petroleum)	500
1-Chloro-1-nitropropane	20	Nickel carbonyl	0.001
Chloroprene (2-chlorobutadiene)	25	Nitrobenzene	1
Cresol (all isomers)	5	Nitroethane	100
Cyclohexane	400	Nitrogen dioxide	5
Cyclohexanol	100	Nitroglycerin	0.5
Cyclohexanone	100	Nitromethane	100
Cyclohexene	400	2-Nitropropane	50
Cyclopropane	400	Nitrotoluene	5
<i>o</i> -Dichlorobenzene	50	Octane	500
Dichlorodifluoromethane	1,000	Ozone	0.1
1,1-Dichloroethane	100	Pentane	1,000
1,2-Dichloroethylene	200	Pentanone (methyl propyl ketone)	200
Dichloroethyl ether	15	Perchloroethylene (tetrachloroethylene)	200
Dichloromonofluoromethane	1,000	Phenol	5
1,1-Dichloro-1-nitroethane	10	Phosgene (carbonyl chloride)	1
Dichlorotetrafluoroethane	1,000	Phosphine	0.05
Diethylamine	25	Phosphorus trichloride	0.5
Dimethylaniline (N-dimethylaniline)	5	Propyl acetate	200
Dimethylsulfate	1	Propyl alcohol (isopropyl alcohol)	400
Dioxane (diethylene dioxide)	100	Propyl ether (isopropyl ether)	200
Ethyl acetate	400	Propylene dichloride (1,2-dichloropropane)	25
Ethyl alcohol (ethanol)	1,000	Stibine	0.1
Ethylamine	25	Stoddard solvent	500
Ethyl benzene	200	Styrene monomer (phenyl ethylene)	20
Ethyl bromide	200	Sulfur dioxide	5
Ethyl chloride	1,000	Sulfur monochloride	5
Ethyl ether	400	1,1,2,2-Tetrachloroethane	20
Ethyl formate	100	Toluene	20
Ethyl silicate	100	<i>o</i> -Toluidine	5
Ethylene chlorohydrin	5	Trichloroethylene	20
Ethylene dibromide (1,2-dibromoethane)	25	Turpentine	20
Ethylene dichloride (1,2-dichloroethane)	100	Vinyl chloride (chloroethene)	20
Ethylene oxide	100	Xylene	20
Fluorine	0.1		
Fluorotrichloromethane	1,000		
Formaldehyde	5		
Gasoline	500		

Table 32-2 (cont.). Threshold values adopted at April 1955 meeting of the American Conference of Governmental Industrial Hygienists

## Established Values (cont.)

## TOXIC DUSTS, FUMES, AND MISTS

SUBSTANCE	MG. PER CU. M.	SUBSTANCE	MG. PER CU. M.
Antimony	0.5	Pentachloronaphthalene	0.5
Arsenic	0.5	Pentachlorophenol	0.5
Barium (soluble compounds)	0.5	Phosphorus (yellow)	0.1
Cadmium	0.1	Phosphorus pentachloride	1
Chlorodiphenyl	1	Phosphorus pentasulfide	1
Chromic acid and chromates as CrO <sub>3</sub>	0.1	Selenium compounds (as Se)	0.1
Cyanide as CN	5	Sulfuric acid	1
Dinitrotoluene	1.5	Tellurium	0.1
Dinitro- <i>o</i> -cresol	0.2	Tetryl (2,4,6-trinitrophenyl- methylnitramine)	1.5
Fluoride	2.5	Trichloronaphthalene	5
Iron oxide fume	15	Trinitrotoluene	1.5
Lead	0.15	Uranium (soluble compounds)	0.05
Magnesium oxide fume	15	Uranium (insoluble compounds)	0.25
Manganese	6	Zinc oxide fumes	15
Mercury	0.1		
Parathion (O,O-Diethyl-O- <i>p</i> - nitrophenyl thiophosphate)	0.1		

## MINERAL DUSTS

SUBSTANCE	MILLION PARTICLES PER CU. FT. OF AIR	SUBSTANCE	MILLION PARTICLES PER CU. FT. OF AIR
Alundum (aluminum oxide)	50	Silica	
Asbestos	5	high (above 50% free SiO <sub>2</sub> )	5
Carborundum (silicon carbide)	50	medium (5 to 50% free SiO <sub>2</sub> )	20
Dust (nuisance, no free silica)	50	low (below 5% free SiO <sub>2</sub> )	50
Mica (below 5% free silica)	20	Slate (below 5% free SiO <sub>2</sub> )	50
Portland cement	50	Soapstone (below 5% free SiO <sub>2</sub> )	20
Talc	20	Total dust (below 5% free SiO <sub>2</sub> )	50

## Tentative Threshold Limit Values

The following values are suggested for further consideration before being presented for adoption as established values.

Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene)	0.25	mg./M <sup>3</sup>
Allyl alcohol	5	p.p.m.
Allyl propyl disulfide	2	p.p.m.
Ammate (ammonium amidosulfate)	15	mg./M <sup>3</sup>
Benzyl chloride	1	p.p.m.
Butyl amine	5	p.p.m.
Butyl mercaptan	10	p.p.m.
Calcium arsenate	0.3	mg./M <sup>3</sup>
Chlordane (1,2,3,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)	2.0	mg./M <sup>3</sup>
Chlorine trifluoride	0.1	p.p.m.
Chlorinated diphenyl oxide	0.5	mg./M <sup>3</sup>
Clag Herbicide (sodium-2,4-dichlorophenoxy ethyl sulfate)	15	mg./M <sup>3</sup>
4-D (2,4-dichlorophenoxyacetic acid)	10	mg./M <sup>3</sup>
D. T. (2,2-bis-( <i>p</i> -chlorophenyl)-1,1,1-trichlorethane)	2.0	mg./M <sup>3</sup>
Acetone alcohol (4-hydroxy-4-methyl pentanone-2)	50	p.p.m.
Isoborane	0.1	p.p.m.
Dieldrin (1,2,3,4,10,10-hexachloro-6,7, epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene)	0.25	mg./M <sup>3</sup>
Fluorodibromomethane	100	p.p.m.
Isobutyl ketone	50	p.p.m.
PN (ethyl- <i>p</i> -nitrophenyl thiono benzene phosphonate)	0.5	mg./M <sup>3</sup>
Thyl mercaptan	250	p.p.m.
Ethylene diamine	10	p.p.m.
Ethylene imine	5	p.p.m.
Vanadium dust	1	mg./M <sup>3</sup>
2-Fural	5	p.p.m.
2-Furyl alcohol	200	p.p.m.
2-Diazine	1	p.p.m.



Table 32-2 (cont.). Threshold values adopted at April 1955 meeting of the American Conference of Governmental Industrial Hygienists

## Tentative Threshold Limit Values (cont.)

Hydrogen bromide	5	p.p.m.
Hydrogen peroxide 90%	1	p.p.m.
Hydroquinone	2	mg. M
Isopropylamine	5	p.p.m.
Lead arsenate	0.2	mg. M
Lindane (hexachlorocyclohexane, gamma isomer)	0.5	mg. M
Malathion (0,0-dimethyl dithio phosphate of diethyl mercaptosuccinate)	15	mg. M
Methoxychlor (2,2-diparamethoxyphenyl-1,1,1-trichloroethane)	15	mg. M
Methyl acetylene	1,000	p.p.m.
Methyl isobutyl carbinol (methyl amyl alcohol)	25	p.p.m.
Methyl mercaptan	50	p.p.m.
Molybdenum		
(soluble compounds)	5	mg. M
(insoluble compounds)	15	mg. M
<i>p</i> -Nitroaniline	1	p.p.m.
Organo mercurials (as mercury)	0.01	mg. M
Perchloromethyl mercaptan	0.1	p.p.m.
Phenylhydrazine	5	p.p.m.
Picric acid	0.1	mg. M
Propylene imine	25	p.p.m.
Pyridine	10	p.p.m.
Quinone	0.1	p.p.m.
Sodium hydroxide	2	mg. M
Sulfur hexafluoride	1,000	p.p.m.
Sulfur pentafluoride	0.025	p.p.m.
TEDP (tetraethyl dithiono pyrophosphate)	0.2	mg. M
TEPP (tetraethyl pyrophosphate)	0.05	mg. M
<i>p</i> -Tertiary butyl toluene	10	p.p.m.
Tetrahydrofuran	75	p.p.m.
Tetranitromethane	1	p.p.m.
Titanium dioxide	15	mg. M
Trifluoromonobromomethane	1,000	p.p.m.
Vanadium		
(V <sub>2</sub> O <sub>5</sub> dust)	0.5	mg. M
(V <sub>2</sub> O <sub>5</sub> fume)	0.1	mg. M
Zirconium	5	mg. M

Material in Table 32-2 from A.M.A. Arch. of Ind. Health, 11:521, 1955.

formed on human beings, but such exposures have been limited in duration and concentration and the circumstances do not duplicate actual working conditions. Third, many attempts have been made to determine safe concentrations directly in industry by correlating the concentration of a substance found in the work room air, with the results of clinical and laboratory examinations of the workers and histories of occupational diseases. If no unusual symptoms were found at the time of the examination and no occupational diseases had been experienced, it was assumed that the existing exposure was safe. This method of determining the maximum allowable concentration, although by far the best procedure, also has certain disadvantages. Air samples taken at the time of a survey represent only the concentrations existing at that time. Since chronic diseases result from prolonged exposure, the concentrations responsible for the disease may have been quite different from those existing at the time of the survey. Finally, in some cases, the maximum allowable concentration values have been based entirely on the sensory response of a group of individuals. This is a satisfactory procedure if these substances have only irritating properties, and if it is definitely specified that the maximum allowable concentration values apply only to sensory responses and not to toxic effects. Unfortunately, such a distinction usually has not been made in listing the maximum allowable concentration values.

In addition to the difficulties in determining the maximum allowable concentration values, there are also difficulties in applying these values to industrial conditions. This is due chiefly to the fact that standards, at least those derived from

laboratory experiments, apply only to specific chemical substances. In industry, today, many chemicals are sold under trade names, and the exact composition is not known to the consumer; many of these are mixtures, and many contain contaminants which are far more toxic than the material itself. Thus, it is often impossible to apply the general accepted maximum allowable concentration values to specific working conditions. It is not safe to apply the maximum allowable concentration determined for one substance to even closely related chemical compounds; all new chemicals must be studied individually. In order to meet this problem, most of the large chemical industries maintain experimental laboratories to study the toxicological properties of their products.

Another factor in considering the maximum allowable concentration values is the duration of exposure. Unless otherwise specified, the maximum allowable concentration applies to an eight-hour exposure. Some maximum allowable concentration values have been set for shorter exposures. As discussed above, it is not possible to determine a safe concentration for a one-hour exposure from the usual eight-hour maximum allowable concentration values.

It is apparent from this discussion that maximum allowable concentrations are not fixed standards of safe working conditions. Some are based on very sound evidence; others represent only the current opinion based on the data available at the time; all are subject to constant revision. However, if used intelligently, they are invaluable guides to industries and health authorities in determining healthy working conditions.

**Analysis of Chemical Substances in Air.** In order to determine if the air contains chemical substances in harmful amounts, it is necessary to analyze the air for both the composition and concentration of the contaminants. Methods of sampling and analyzing the air cannot be reviewed here. They are described in detail in a number of books and scientific journals to which reference should be made. The most inclusive references, specifically applied to industrial hygiene, are listed at the end of this chapter.

**Methods of Expressing the Concentration of Chemical Substances in the Air.** The following list indicates the usual form of expressing the concentration of chemical substances in the air for industrial hygiene purposes:

Hard rock dusts: number of particles per cubic foot of air (usually as millions).

Metallic dusts and fumes: milligrams per cubic meter of air.

Gases and vapors: parts of gas or vapor per million parts of air by volume, usually written parts per million (p.p.m.); or milligrams per liter.

In order to convert the volume of a gas to the weight of the gas, i.e., to convert parts per million by volume to milligrams per liter, the following formula must be used:

$$\text{mg./liter} = \frac{\text{gram molecular weight} \times \text{p.p.m.}}{22,400} \quad (0^\circ \text{C})$$

## THE DUSTS

### GENERAL CONSIDERATIONS

**Protection of the Body Against Foreign Particles in the Inspired Air.** Before considering the effects of industrial dusts it is well to review the normal protective mechanisms of the respiratory tract against foreign substances. When dust particles



are inhaled, many of those which come into contact with the mucous secretions of the upper respiratory tract are deposited on the surface of the mucous membrane and subsequently are eliminated. The structure of the nose is admirably adapted to this process, since the upward flow of air is abruptly deflected downward; the larger dust particles are thrown against the wall of the pharynx by this bafflelike arrangement. The cilia, which line the respiratory tract as far down as the bronchioles, sweep the dust particles and mucous secretions toward the mouth. The peristaltic motion in the bronchioles, and the coughing and sneezing reflexes also are important in the removal of foreign particles. Those dust particles which reach the alveoli are phagocytosed by the macrophages in the lungs, and, for the most part, are removed through the lymph channels to the lymph glands. By these various mechanisms the respiratory passages and alveoli are kept relatively free of dust particles. When large quantities of dust are inhaled, some of the dust-filled macrophages will remain in the alveolar tissue.

From the viewpoint of health, the size of the dust particles is of greatest importance. Dust particles which are more than 10 microns in diameter settle out of the air rapidly, and only particles below 5 microns in diameter remain suspended in the air for any length of time. Dust particles larger than 3 microns in diameter are filtered out in the upper respiratory passages. Particles below 3 microns may penetrate to the alveoli and remain there. As the particle size decreases from 3 to 1 micron, the percentage deposited in the alveoli increases, but the retention decreases as the size is reduced from one micron to 0.25 micron. The retention of particles below 0.25 micron has not been investigated, but the retention probably increases again because of the Brownian movement (Brown and others, 1950).

**Classification of Dusts and Fumes in Relation to Health.** The dusts and fumes may be classified into several groups according to their principal effects on health (1) hard rock or mineral dusts or pneumoconiosis-producing dusts, (2) organic dusts of plant and animal origin or allergic dusts, (3) metallic dusts and fumes and other inorganic toxic dusts and fumes, (4) dusts from organic material (see organic compounds).

**Types of Tissue Reaction to Mineral or Hard Rock Dusts.** The hard rock or mineral dusts, i.e., dusts which arise from the crushing of earthy materials, when considered in regard to their effects on the tissues, fall into three groups (Mille and Sayers, 1935):

1. *Absorptive dusts* which are absorbed and do not produce any visible gross damage to the lungs. Examples are: calcite, limestone, calcium carbonate, gypsum and Portland cement.
2. *Relatively inert dusts* which are relatively insoluble and which cause, if anything, only low grade tissue reaction without any effect on pulmonary function. Hematite, carborundum, soapstone, and feldspar are examples.
3. *Fibrosis-producing dusts* which cause marked tissue reaction, the outstanding feature of which is a proliferation of fibrous tissue. Free silicon dioxide (quartz) and asbestos are the important members of this group.

The mineral dusts as encountered in industry are, in general, not toxic to the internal organs, but produce their effects chiefly in the lungs.

**Terminology of Lung Conditions Due to Dusts.** Some confusion has arisen in the medical literature and in compensation cases over the terminology employed for diseases of the lungs due to dust exposures, especially with regard to the term

pneumoconiosis and silicosis. The term pneumoconiosis, as now used, indicates any type of pulmonary reaction to inhaled dust without any implication as to the character or severity of the reaction or to the effect on respiratory function. It is a general term to cover all conditions whether or not they are of clinical significance. The specific types of pneumoconioses are named according to the etiological agent, such as silicosis, asbestosis, siderosis, anthracosis. If the definition of pneumoconiosis given above is used, silicosis is a pneumoconiosis due to the inhalation of free silica dust ( $\text{SiO}_2$ ), and asbestosis is a pneumoconiosis due to asbestos dust. Fibrosis of one type or another is characteristic of these conditions. On the other hand, siderosis is a pneumoconiosis due to the inhalation of relatively pure iron dust which causes no significant fibrosis. Hence, this condition is called a benign nonspecific pneumoconiosis.

### SILICOSIS \*

**Environmental Aspects.** Silicosis has been a well recognized disease for many years. As far back as the seventeenth century, the pathology of stone-cutters' lungs was described, and even the relation of silicosis to tuberculosis was noted. Löhneiss in 1690 said of miners: "The dust and stones fall upon the lung, and the men get lung diseases and at last take consumption." (Teleky, 1948.)

In spite of the fact that silicosis has been known for a long time, the exact mechanism responsible for this lung condition is not understood completely. However, many studies of this disease have been made and a number of facts regarding silicosis have been well established.

**TYPE OF DUST RESPONSIBLE FOR SILICOSIS.** Free silica or silicon dioxide ( $\text{SiO}_2$ ) is responsible for silicosis. This substance occurs in both crystalline and amorphous forms. The crystalline forms include: quartz, chert, sandstone, gritstone, gannister, quartzite, beach sand, jasper, tridymite, cristobolite, chalcedony, tripole, and others. It is believed that all of these forms of  $\text{SiO}_2$  are capable of producing fibrosis when in direct contact with the lung tissue. The common amorphous forms are opal and diatomaceous earth. Gardner stated that opal, although mildly irritating, did not cause progressive fibrosis like quartz, whereas celite, an amorphous silica composed of silicious diatome shells, provoked a progressive fibrosis indistinguishable from the reaction to quartz (Gardner, 1938). According to Vorwald and his associates (1949), "clinical and experimental evidence indicate that both the crude and fluxed calcined diatomaceous earth are capable of producing pulmonary fibrosis, the latter more than the former."

Silica, when combined with other chemical substances as in silicates, in general does not cause progressive pulmonary fibrosis. Asbestos is an exception to this and will be discussed later. Some reports have indicated that certain other silicates such as talc and mica may produce fibrosis, but the evidence is not conclusive at present. Thus, the two most important mineral dusts which have been proved definitely to produce pulmonary fibrosis leading to impairment of respiratory function are silicon dioxide and asbestos.

**INDUSTRIES WITH SILICA EXPOSURES.** Exposure to free silica is commonly found in a number of occupations: in mining operations where the strata of rock

\* Much of the material on silicosis has been taken directly from papers by the late Dr. U. Gardner, former Director of the Saranac Laboratory. These papers (Gardner, 1937, 1938, 1940, and 1942) are listed under General References.



contain a high percentage of free silica; in building and construction work which requires drilling through silica-containing rock; in quarrying and dressing of granite; in work with sandstone and flint; in the manufacture and use of certain abrasives; in sandblasting, metal grinding, and wood finishing; in the ceramic and glass industries; in foundries; in the soap powder industry; in the manufacture and replacement of silica bricks in furnaces; and in a number of other industries. In former years, grinding wheels were composed of sandstone or quartz, but, fortunately, these are being replaced with carborundum and other synthetic abrasive materials which do not yield free silica dust.

**INCIDENCE OF SILICOSIS IN THE UNITED STATES.** In 1940 the United States Public Health Service estimated that about 1,420,500 persons in this country were employed in occupations where there was a potential exposure to free silica (Bloomfield et al., 1940), but the incidence of silicosis in this group was not known. Some authorities estimated that probably only 25 per cent of the men exposed to free silica had silicosis. Studies in different industries have shown that anywhere from 2 to 75 per cent of the workers exposed to silica dust may have silicosis.

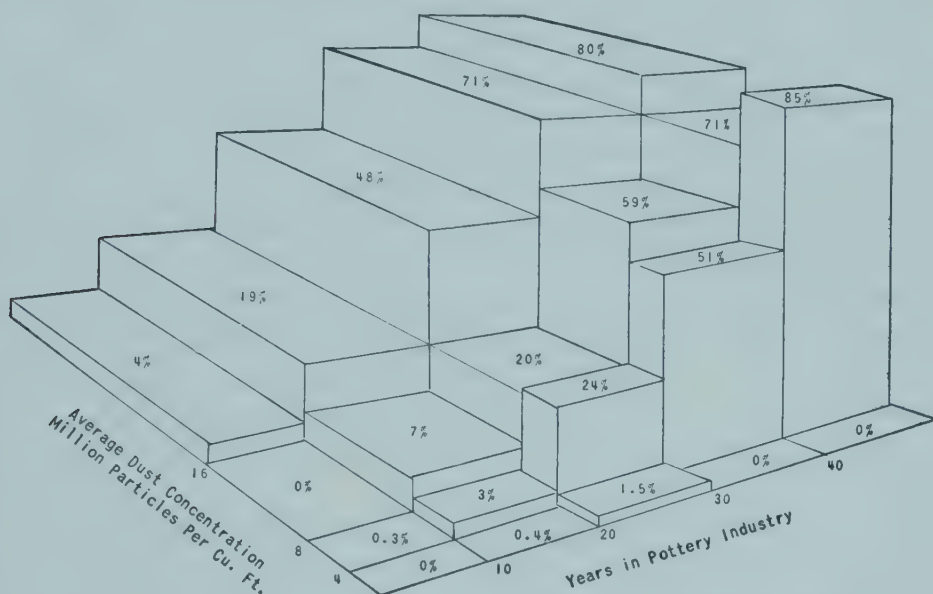
The incidence of silicosis varies with a number of factors, the most important being: (1) the concentration of dust in the air, (2) the percentage of free silica in the dust, (3) the duration of exposure, (4) the size of the dust particles, (5) the presence of other dusts, and (6) individual susceptibility.

The incidence of silicosis increases progressively with an increase in the concentration of dust in the air, with the percentage of free silica in the dust, and with the length of exposure. These relationships have been shown in a number of studies. Figures 32-1 and 32-2, which are taken from a study of the pottery industry, illustrate these relationships. Most cases of silicosis require from three to six, and more often, from 10 to 12 years of exposure for their development. However, there are some cases on record in which extensive silicosis has appeared after two years of exposure to high concentrations of very fine silica dust. In general, the higher the concentration of silica dust in the air, the greater the incidence of silicosis. The concentration of silica dust which appears to be safe for the majority of workers, according to the information available at present, is shown in Table 32-2.

The size of the particles is of great importance in determining the effect of silica dust. As discussed above, the penetration and retention of dust particles in the lungs varies with the size. The rate and extent of the tissue reaction is proportional to the surface area of the dust; hence, for any given mass, the smaller the particles, the greater the reaction. Furthermore, the type of tissue reaction varies with the size of the particles. Silica particles between 3 and 0.5 microns produce the typical nodular fibrosis; sub-microscopic sizes produce a diffuse fibrosis. Colloidal silica in a dispersed phase causes bronchoconstriction and almost instant death if injected intravenously in large doses. Some authorities believe that the effects of sub-microscopic particles of silica are more closely related to their colloidal nature than to their specific chemical composition.

The presence of other dusts in an atmosphere containing silica may alter the effect of the silica dust. Certain dusts, such as calcined gypsum, when suspended in the air with quartz dust, cause flocculation of the dust particles. These large conglomerate masses settle out of the air rapidly and are filtered out of the inspired air by the upper respiratory tract. As a result, less free silica reaches the lung tissue.

Other dusts, such as aluminum and iron, in certain forms, produce a more or less stable coating on the silica dust particles and thus prevent the action of the silica particles on the lung tissue. This reaction may occur whenever the two dusts come into intimate contact either in the air or in the lungs. Because of this reaction, it

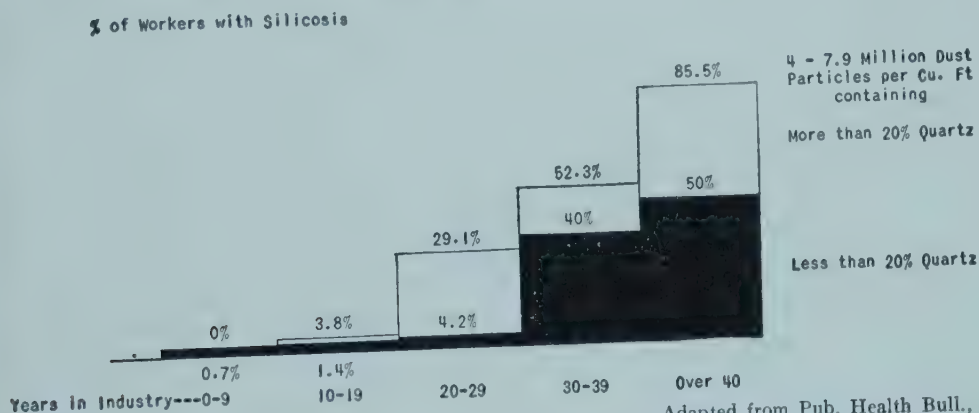


From Pub. Health Bull., No. 244, 1939.

Fig. 32-1. Percentage of workers with silicosis (all stages) in relation to average dust concentration and length of employment in pottery industry.

has been suggested that aluminum dust might be used for the treatment and prevention of silicosis. (See page 1050.)

**Medical Aspects. REACTION OF THE LUNG TISSUE TO SILICA DUST.** The typical reaction to silica dust is a proliferation of the connective tissue, leading to the



Adapted from Pub. Health Bull., No. 244.

Fig. 32-2. Percentage of workers with silicosis in relation to quartz content of dust and length of employment.

formation of dense, fibrous nodules 3 to 4 mm. in diameter. These nodules form first along the lymph trunks and later directly in the lung tissue. Contiguous nodules may fuse together to form simple localized conglomerate foci. If the exposure ceases, the nodules continue to progress until they have been completely formed but very few new nodules will appear. In some cases, massive conglomerate fibrosis occurs. Most authorities believe that an associated infection, usually tuberculous,



is the most important cause of this conglomerate reaction. Where excessive quantities of exceedingly fine pure silica exist, so-called rapidly developing silicosis may occur. In these cases, the alveolar walls become thickened, microscopic nodes develop throughout the pulmonary tissue, and actively proliferating phagocytes fill the air spaces.

The effect of silica dust is not specific to lung tissue. Silica particles may produce fibrous nodules in almost any tissue and in practically all species of laboratory animals. Various theories have been advanced to explain this tissue reaction to silica particles, but none has been proved. The fibrosis-producing property of silica dust is not due to the mechanical factors of hardness and sharpness of the silica particles nor to silica in dissolved form apart from the particulate form but appears to be related to the crystal structure or surface properties of the dust.

**SYMPTOMS, DISABILITY AND PROGNOSIS IN SILICOSIS.** Simple nodular silicosis, in the absence of infection, does not seriously interfere with ordinary work. Shortness of breath occurs only on sudden, unusual exertion. If further exposure to silica dust is prevented, these men may continue to work and live normally. The clinical symptoms frequently are not commensurate with the roentgenological manifestations.

Massive conglomerate silicosis, on the other hand, may cause severe dyspnea with emphysema and subsequent cardiac involvement. If the disease is not too extensive and is not complicated by tuberculous infection, these patients may perform light work. Large conglomerations and advanced silicotuberculous lesions are incapacitating, and the prognosis is not good.

Silicosis presents one of the most difficult problems in the compensation for occupational diseases, since there are no physiological, chemical, clinical, or roentgenologic tests which indicate with any accuracy the degree of disability below that of complete disablement.

**DIAGNOSIS OF SILICOSIS.** Because of the lack of any specific clinical symptoms, a diagnosis of silicosis must be based principally on a history of occupational exposure to free silica dust and on a characteristic appearance of the roentgenograms, read by a roentgenologist trained in silicosis.

**SILICOSIS AND TUBERCULOSIS.** There is ample evidence from statistical surveys, clinical studies, and animal experimentation that silicosis lowers the resistance to tuberculosis. In fact, tuberculosis is the major cause of disability and death in silicosis. The high rate of tuberculosis among persons engaged in certain occupations involving exposure to silica dust is shown in Table 32-3, which was compiled by the Metropolitan Life Insurance Company (Lanza and Vane, 1934). Even simple nodular silicosis is associated with a definite increase in susceptibility to tuberculosis. According to Gardner: "The infection may develop as a result of reactivation of a pre-existing latent tuberculous focus but opinion today is unanimous that new infections from without are a more common cause. Most or possibly all of the massive fibrous lesions of silicosis are developed on a background of tuberculosis." (Gardner, 1940.)

The clinical picture of tuberculosilicosis differs from that of tuberculosis as usually seen. The symptoms of intoxication are often masked until the condition reaches the advanced stages.

Since exogenous infections are believed to be the chief cause of tuberculosilicosis, it is evident that contacts of silicotics with open cases of tuberculosis should be

Table 32-3. Respiratory tuberculosis in relation to silicosis. Ratio of actual number of deaths to expected number of deaths from respiratory tuberculosis in certain occupations involving exposure to silica dust. Mortality experience of 12 life insurance companies 1915-26

OCCUPATION	NUMBER OF DEATHS DUE TO RESPIRATORY TUBERCULOSIS		PERCENTAGE OF ACTUAL TO EXPECTED
	ACTUAL	EXPECTED	
Metal mine operatives underground			
Gold and silver mines	9	1.12	804
Lead and zinc mines	11	0.60	1,833
Copper mines	24	2.63	913
Iron mines	4	1.54	260
Quarry operatives	7	2.66	263
Stonecutters			
Granite and sandstone	16	1.64	976
Marble and limestone	3	1.02	294
Metal industries			
Grinders	7	3.33	210
Buffers and polishers	10	6.80	147
Chippers (not ship)	8	1.30	615
Chore makers and sand moulders	3	2.92	103
Iron and steel foundries			
Moulders, founders and casters	24	13.38	179
Drillers, flaskmakers, machine hands, mixers, etc.	7	3.03	231

From Lanza, A. T., and Vane, R. J., *Am. Rev. Tuberc.*, 29:8, 1934.

rigidly avoided. In areas where the tuberculosis death rate in the general population is low, the rate among silicotics is also lower than in other less favorable areas. Recent experiments on animals suggest that BCG vaccination may be dangerous in cases of silicosis (Vorwald and others, 1950).

At present, there is no evidence to indicate that exposure to any other inorganic dusts except free  $\text{SiO}_2$  increases susceptibility to tuberculosis (see also Asbestosis, page 1051).

**SILICOSIS AND LUNG CANCER.** There is ample evidence that silica dust does not initiate or favor the development of pulmonary carcinoma. Vorwald and Karr (1938) studied the results of radiologic examination of 12,206 silicotics. Only three silicotics, or 0.005 per cent of the group, were found to have lung cancer. A survey of five industries, covering 15,587 persons and including 1,357 cases of silicosis was made by the Saranac Laboratory. Only one case of pulmonary carcinoma was found in the silicotics (0.074 per cent), and two in the nonsilicotics (0.014 per cent). Autopsy observations made on native and European miners in South Africa, many of whom had silicosis, showed similar negative results. Furthermore, animal experiments also have given no evidence that lung tumors result from exposure to silica dust. Thus, there is no evidence that lung cancer is related in any way to silicosis.

**SILICOSIS AND PNEUMONIA.** There is no evidence, at the present time, to indicate that exposure to silica dust increases susceptibility to lobar pneumonia. Although high mortality and morbidity rates for pneumonia have been reported in some silica industries, such as in foundries and mines, factors other than silica dust appear to be responsible for this. Furthermore, abnormally high pneumonia rates have not been found in other industries and mines where exposure to silica



dust occurs. Laboratory experiments on animals, carried out in the author's laboratory, have shown that exposure of rats to high concentrations of silica dust does not lower their resistance to pneumococci Type I, injected intrabronchially. In fact, under some conditions, the rats were more resistant to the lobar pneumonia following prolonged exposure to silica dust. The relation of silicosis to bronchopneumonia is not clear.

**TREATMENT AND PREVENTION.** There is no known treatment for silicosis which will reduce the fibrosis, although relief of symptoms to some degree may be obtained in some cases. Because aluminum dust produces a coating on silica particles, the inhalation of aluminum dust has been tried as a therapeutic measure. The Council on Industrial Health and the Council on Pharmacy and Chemistry of the American Medical Association summarized the available data in 1949. Their conclusions were as follows: "Studies on the therapy of silicosis thus far have been inadequately controlled. The majority of subjects have reported subjective improvement, apparently of psychic origin. No convincing evidence of objective improvement either of pulmonary function or by roentgen ray has been forthcoming. Certain cases have shown eventual progression by roentgen ray subsequent to aluminum therapy under present conditions of dosage." (Brown and Van Winkle, 1949.)

Prevention is the only positive means of attack on silicosis. With modern engineering technics, there is no reason why silica exposures cannot be reduced to safe concentrations and silicosis completely eliminated in the course of a few years. Until that time comes, all persons working in such atmospheres should be examined clinically and radiologically at frequent intervals by a competent physician. Those with silicosis should be protected from further exposure to silica dust. Persons with tuberculous lesions should not be employed where silica exposures exist.

Measures for the prevention of exposure to dusts and fumes, including silica dust, are discussed under prevention of occupational diseases due to chemical substances, on pages 1086 to 1091.

### ASBESTOSIS

Asbestosis is a pneumoconiosis due to the inhalation of asbestos dust.

**Nature of Asbestos.** Asbestos is a general term which is applied to minerals of fibrous form. These minerals are silicates of varying composition which fall into two distinct groups, serpentine and amphibole. Chrysotile, a hydrous magnesium silicate of the serpentine type, is by far the most common type of asbestos. The amphibole group includes various silicates of iron, calcium, magnesium, and, in some cases, sodium; examples are crocidolite and tremolite. Asbestos fibers are usually from 20 to 500 microns in length, and from 0.5 to 50 microns in diameter. The fibers of crocidolite are much stiffer and straighter than those of chrysotile.

**Reaction of Tissues to Asbestos.** Pulmonary fibrosis results in man and in some animals from the inhalation of chrysotile, the serpentine type of asbestos. This fibrosis differs from that which occurs in silicosis, being a fine, interstitial, diffuse fibrosis around the terminal bronchioles, rather than nodulation. It is believed that fibers up to 200 microns in length can penetrate the respiratory tract if the maximum diameter does not exceed 5 microns. Fibers which are inhaled accumulate in the lumen of the respiratory bronchioles and later in the alveolar ducts but do not seem to penetrate to the alveoli.

It is generally believed that the fibrosis is due to the mechanical irritation of the long fibers (between 20 and 50 microns in length). Presumably the motion of the lung tissue in breathing, combined with the filamented structure and the flexibility of the fibers are responsible for this irritating effect. This theory is supported by the fact that asbestos fibers, unlike silica dust, are inactive when in contact with other tissues, such as the liver, where there is no mobility, and by the fact that they do not cause pulmonary fibrosis if the fibers are short or are ground to small particle size. The stiff, straight fibers of crocidolite do not stay in the walls of the bronchioles, but pass on into the alveoli, and do not appear to cause fibrosis. Fibrosis occurs only where there is mechanical rubbing of the tissue against the fibers. Commercial talc or its component materials, such as tremolite, after prolonged exposure appears to cause a fibrosis resembling asbestosis.

**Clinical Aspects.** The clinical symptoms are due to the fibrosis and the concomitant pathological changes, chiefly emphysema and bronchiectasis. Progressive dyspnea, which can lead to disablement, is the chief symptom. Cough and loss of weight also occur. Death is due to secondary respiratory infection or to cardiac involvement. It is generally believed that the fibrosis will not progress after cessation of exposure.

Diagnosis of asbestosis must rest on a history of exposure to asbestos dust, on the clinical symptoms, and on the radiological examination. The presence of asbestosis bodies in the sputum is not of any diagnostic value. Asbestosis bodies are fibers which are surrounded by an iron-containing coating and which have fractured to give peculiar structures. They may be formed from any fibrous material, including asbestos, but are neither indicative of the degree of exposure nor associated with the fibrosis.

Although some cases of tuberculosis have been reported in asbestos workers, there is no convincing evidence, either clinical or experimental, that asbestosis increases susceptibility to tuberculous infection. A number of cases of lung cancer associated with asbestosis have been found in various autopsy studies especially in Great Britain. Authorities differ in their opinion regarding the possible role of asbestos in the etiology of lung cancer.

There is no known treatment for asbestosis; prevention of exposure to asbestos dust is the only effective weapon against this condition.

**Incidence of Asbestosis.** The incidence of asbestosis in persons working in environments containing asbestos dust varies with the extent and duration of exposure. The disease does not usually appear until after 5 to 10 years of exposure. The incidence of asbestosis increases progressively with the duration of exposure. More than half of the workers with 20 years of exposure have the disease. Studies in asbestos industries indicated that 5,000,000 particles per cubic foot of air is the maximum safe concentration, but recent work suggests that the standards may vary with the percentage of long particles in the dust.

#### OTHER HARD ROCK AND MINERAL DUSTS

**Siderosis.** Exposure to iron oxide produces a benign pneumoconiosis called siderosis. "By itself this mineral provokes no significant fibrosis but merely pigmentation, which has no influence on pulmonary function" (Gardner, 1940). However, roentgenograms of workers exposed to the iron oxide dust show nodular shadows simulating those of silicosis. Clinical studies of these workers, autopsy



findings, and animal experimentation have proved that these shadows are due not to fibrosis but to the radio-opaque iron oxide which had accumulated in foci throughout the lungs. Studies on animals indicate that iron oxide dust does not cause fibrosis or affect the course of experimentally induced tuberculosis.

**Coal Dust.** In this country coal dust has been considered a benign material which, in the absence of free silica, produces only a slight chronic inflammatory reaction with little or no fibrosis and no disability. However, in recent years British and European investigators (Fletcher, 1955) have described two types of pneumoconioses in coal workers. Simple pneumoconiosis is characterized by focal deposits of coal dust around respiratory bronchioles with reticulin fibrosis and, in the elderly, focal emphysema. This condition rarely causes severe disability. Complicated pneumoconiosis, which occurs only in the presence of moderately advanced simple pneumoconiosis, is characterized by massive conglomerate lesions with cavitation and is apparently due to an associated action of coal dust and tuberculous infection. This type leads to a high rate of disability and death.

### DUSTS OF PLANT ORIGIN

**General Effects.** Public health officials are often asked if grain, wood, cotton and other dusts of plant origin produce any harmful effects on the lungs or other tissues. In general, it can be said that these natural organic dusts may cause allergic reactions in susceptible persons leading to a variety of conditions in the respiratory tract, skin or other tissues, and that many of these are irritating to the respiratory tract and skin even when no allergic reactions are visible. In some cases, the effects are due to the smuts, mites, fungi or other parasites which contaminate these dusts. In other cases, the irritation is due to the physical rather than to the chemical properties of the dust. Many natural organic dusts present an additional hazard due to their high degree of inflammability. Dust clouds of flour, wood or tobacco may be explosive.

There is no evidence that any of these dusts produce fibrosis of the lungs, such as is found in cases of silicosis or asbestosis. In spite of statements in the literature that a high rate of tuberculosis exists among workers exposed to cotton, tobacco, and grain dusts, and that exposure to these dusts is partly responsible for this rate, there is no sound evidence to support this belief. Tuberculosis rates are not consistently high throughout the occupations which involve exposure to these natural dusts, and a low standard of living appears to be the major factor in those instances where a high tuberculosis rate does occur. There is also no evidence at the present time that cancer of the respiratory tract, skin or any other tissue is related to the natural organic dusts encountered in occupational exposures.

The three dusts of plant origin which have been considered most frequently to present industrial health problems are cotton, grain, and wood dust.

**Effects of Specific Dusts. COTTON DUST.** The U.S. Public Health Service has recently published a review of the literature on the effects of cotton dust on the respiratory tract (Caminita and others, 1947). The principal points brought out in their report may be summarized as follows:

1. A survey of the literature indicates that "upper respiratory tract affections, ranging from chronic irritation of the nose and throat to bronchitis, complicated by asthma and/or emphysema, and pneumonia are common among cotton workers. No conditions simulating silicosis have been reported. There is no increased incidence of tuberculosis."

2. "There is considerable evidence in support of the assumption that cotton dust is the chief cause of respiratory tract affections among cotton workers, and that it can act as a mechanical irritant, and as a source of allergens, of histamine, and of the toxic metabolic products of micro-organisms."

3. "Four separate disease entities associated with the inhalation of cotton dust have been reported. These are mill fever, byssinosis, weaver's cough, and an acute illness among workers handling lowgrade stained cotton." Mill fever resembles metal fume fever. It is usually attributed to the inhalation of cotton dust. Weaver's cough is an acute illness which occurs among operatives, both old and new, who handle mildewed yarn; examination of the dust revealed *Penicillium*, *Mucor*, *Aspergilli*, and an unidentified fungus. The acute illness which occurs among workers handling low grade stained cotton has been shown to be due to *Aerobacter cloacae* endotoxin resulting from contamination of the cotton while in the field. "Byssinosis occurs in subjects who have had long and continuous exposure to cotton dust. It is characterized by chronic bronchitis complicated by emphysema and, in the later stages of some cases, asthma. It is attributed to the inhalation of cotton dust."

4. Most of the cases of illness in cotton workers have been reported in the foreign literature. "In the United States, the problem of serious dust disease among cotton workers is hardly known to exist. It is possible that it does exist but goes unrecognized or is ignored, or is obviated by labor turnover."

GRAIN DUST. Allergic reactions in susceptible persons may result from exposure to grain dust itself and to the smuts which may infect the grain. So-called grain itch is due to the parasite, *Pediculoides ventricosus*, on the grain. Lung infections may result from contaminating fungi and molds. The hairs from the ripened head of grain are sharp and when inhaled cause direct irritation by adhering to the moist mucous membrane. Grain dust appears to cause a temporary malady like metal fume fever. Insecticides adhering to the grain also may present a hazard.

WOOD DUST. Except for the irritative and allergic effects described above, there is no sound evidence that wood dust produces harmful effects in man. Because of the large particle size and the fact that wood dusts are easily wetted, it is doubtful if any significant amount of wood dust reaches the alveoli. Woodworkers, however, may be exposed to silica dust if they are using abrasives containing free silica and fibrosis of the lungs may occur, but this condition is attributable to the silica and not to the wood dust.

## THE METALS, THEIR DUSTS, FUMES AND VAPORS

From a preventive medical viewpoint, it is desirable to know which of the metals and their compounds encountered in industrial exposures are relatively harmless, which are irritative or damaging to the respiratory tract, which produce dermatoses, and which produce harmful effects on the internal tissues of the body after absorption. Since the effects of the metals vary with the type of compound, with the mode of exposure, and with other factors, it is difficult to make any general statement as to their effects. However, a very general classification can be given which includes the more common metals and their compounds. This grouping applies only to the usual type of exposure found in industry, not to situations where the chemical substances are ingested or injected into the tissues.

1. Metallic dusts and fumes which are believed to be relatively harmless: copper, gallium, indium, iron, molybdenum, palladium, silver (except skin effects), and tin.



2. Metallic fumes which produce metal fume fever: chiefly zinc and magnesium as oxides, although almost any metallic oxide may be effective.

3. Metallic dusts and fumes which, in one form or another, are irritative or produce some harmful effect on the respiratory tract: aluminum (see Shaver's Disease), beryllium, cadmium, chromium, manganese, nickel, platinum, and vanadium.

4. Metals or their compounds which have an effect on the skin (usually when in the form of a salt with chlorine, fluorine, or sulfur): aluminum, antimony, barium, beryllium, calcium, chromium, copper, magnesium (as splinters), mercury, nickel, potassium, radioactive metals, silver, sodium, zinc, and others.

5. Metallic dusts and fumes which may be absorbed and thereby produce harmful effects in the internal organs of the body: antimony, beryllium, lead, manganese, mercury, radioactive metals, thallium, uranium, vanadium, and others.

The metals discussed here have been chosen either because they are widely used and produce serious or unusual injury or because their harmful effects have been recognized only recently. The metals which will be discussed in this section are: aluminum, beryllium, cadmium, chromium, lead, manganese, mercury, and uranium.

#### ALUMINUM

No harmful effects of aluminum dust on the lungs have been reported in the aluminum workers in this country or in England. A peculiar pneumoconiosis due to aluminum has been described by some European scientists. This condition somewhat resembles the symptoms of Shaver's disease described below. However, there appeared to be no correlation between the exposure, the radiological picture, and the symptoms. Unless further evidence is forthcoming, it can be said that aluminum dust in the ordinary concentrations and form found in industries causes no damage to the lungs.

**Shaver's Disease.** A previously unrecognized condition of the lungs has recently been described by Shaver (1947). The symptoms consist of an interstitial fibrosis and profound emphysema leading in many cases to spontaneous pneumothorax. Death has followed in some cases. All of the cases thus far described have occurred in men who were exposed to dense fumes which resulted from heating bauxite, iron, and coke to very high temperatures in the manufacture of corundum. The fumes contain high concentrations of aluminum and silica in exceedingly small particle sizes, even down to 0.05 micron in diameter. The condition has been reproduced in animals and appears to be due to the aluminum oxide fraction of the fume.

#### BERYLLIUM

It was not until World War II that beryllium and its compounds assumed industrial importance. It is not surprising, therefore, that the harmful effects of these substances have been recognized only in the past few years. This metal will be discussed in some detail because the toxicity of beryllium has been recognized only recently and because serious effects may occur from exposure to beryllium both inside and outside of industry.

**Industrial Exposures to Beryllium.** Exposure to beryllium or its compounds may occur in plants producing beryllium from the ore, in atomic energy work, in the founding and use of beryllium alloys of copper and other metals, in the produc-

tion of incandescent lamps, roentgen-ray and electronic tubes; in the manufacture of ceramics, vitreous enamels, gas mantels, textile fibers, etc.; in laboratory research work of various types; and in the manufacture of phosphors for fluorescent lamps, neon signs, and luminous indicators. (A beryllium phosphor was used originally to coat the inside of fluorescent tubes but was abandoned because of its toxicity.)

The most common forms of beryllium include: beryllium metal (which in dust form is probably coated with a layer of beryllium oxide), beryllium oxides of various types, beryllium sulfates, fluoride, hydroxide, chlorides, and carbonates. Beryllium exists in nature as a complex aluminum beryllium silicate known as beryl.

**Effects of Beryllium on Health.** Some of the earlier investigators reported that the beryllium ion was not toxic, and that the toxic properties of some of the beryllium compounds were due to the other ions present in the material, notably, to the fluoride and sulfate radicals. More recent work has indicated that the toxic effects are the result of the action of the beryllium ion itself and are not due to the associated anions, although these may exert an enhancing effect on the action of the beryllium ion.

The principal clinical conditions which have resulted in persons exposed to beryllium compounds are: (1) acute pneumonitis, (2) chronic berylliosis or pulmonary granulomatosis, and (3) skin lesions of various types, including granulomatous reactions. In animals, acute pneumonitis, osteogenic sarcomas, and a number of toxic reactions have been produced; and chronic pulmonary granulomatosis and lung tumors have been reported in some strains of rats.

Acute pneumonitis has occurred in workers exposed to the dusts and fumes of beryllium metal, some of the beryllium oxides, and the sulfates, fluoride, hydroxide, and chlorides. The majority of these cases have occurred in the basic industries using and extracting the beryllium ore. The symptoms of acute beryllium pneumonitis include nasopharyngitis, cough, substernal pains, exertion dyspnea, cyanosis, anorexia, loss of weight, and fatigue. Later, tracheitis and bronchitis develop with a roentgenographic picture of diffuse haziness. The pathological changes are those of a chemical pneumonia with edema, exudate, and hemorrhage. The disease is progressive from onset up to two or three weeks. Death has occurred in some cases, but recovery has been complete within four to five months in other cases. Cases of acute pneumonitis have resulted even from single short exposures to beryllium compounds.

The chronic lung conditions were first noticed in this country in workers using beryllium compounds in the manufacture of fluorescent lamps. Subsequently, cases have occurred in the other industries listed above. However, no cases have been reported in the processing of beryl ore or in the use of finished beryllium alloys containing less than 2 per cent of the element. (Hardy, 1955).

The chronic disease presents a different syndrome from the acute form. One of its outstanding features is the delayed onset. In some cases no symptoms have appeared until months or even years after the end of the exposure to beryllium compounds, whereas in other cases symptoms have developed during the exposure. Continuous loss of weight, dyspnea, weakness, and fatigue are the outstanding features of the disease. The dyspnea becomes progressively worse. Death or considerable disability have resulted in the majority of these cases. The pathological picture is that of a diffuse pulmonary reaction with nodular granulomatous lesions about 1 mm. in diameter distributed fairly uniformly throughout the lungs. Because



of this feature, the early cases were mistakenly diagnosed as Boeck's sarcoid. Some authorities have expressed the belief that the chronic disease is in the nature of an allergic reaction (Sterner and Eisenbud, 1951).

Beryllium is of special importance from a public health viewpoint, not only because of the industrial cases, but also because of the so-called neighborhood cases. Ten persons who had had no industrial exposure to beryllium developed a condition which in every respect was similar to the chronic pulmonary granulomatosis due to beryllium. These patients lived within three quarters of a mile of a plant producing beryllium compounds from the ore. It is believed that fine beryllium dust, through pollution of the atmosphere, was responsible for these cases. Another person, who resided two miles from the plant and who had not worked in the plant, also developed the same disease. The exposure in this case was attributed to the handling of contaminated work clothes of an employee who lived in this house.

The degree of exposure was so low in these "neighborhood" cases and in some of the industrial cases that a threshold limit has not been adopted as yet. However, the Atomic Energy Commission has recommended for their plants the following tentative limits: for inplant exposures, 2 micrograms per cubic meter as an average concentration throughout an 8 hour day and 25 micrograms per cubic meter for any period of time, however short; and for air contamination in the neighborhood of a plant handling beryllium compounds, 0.01 microgram per cubic meter as the average monthly concentration in the breathing zone (Sterner and Eisenbud, 1951).

Skin conditions which result from exposure to beryllium include: contact dermatitis, skin ulcers, sarcoid-like lesions arising spontaneously in patients with the chronic type of lung disease, and subcutaneous granuloma (similar to the lung lesions) resulting from subcutaneous implantations of beryllium compounds. The last type has occurred chiefly in cases where broken fragments of fluorescent lamps have penetrated the skin. In one instance, a 12-year-old boy used a discarded fluorescent lamp from a dump pile as a baseball bat. Pieces of the glass became imbedded in his neck. The doctor cleaned out the wound and sutured it. Some weeks later, the boy developed multiple granuloma, involving the subcutaneous tissue and mandible, as a result of the beryllium from the fluorescent tube which remained in the tissues. The lung and skin manifestations are the chief effects of beryllium exposure which have been reported in man. However, it may possibly produce other effects, since it has been shown that beryllium inhibits the alkaline phosphatase system and that the intravenous injection of beryllium compounds produces osteogenic sarcomas in rabbits. No sarcomas have been reported in man up to the present time.

**Prevention of Beryllium Exposures.** Because minute quantities of beryllium or its compounds are able to cause serious or even fatal injury, extreme precautions should be taken to prevent workers from inhaling the dust or fumes. Skin contact should be avoided and any material that gets into the skin should be removed at once. The general measures for the prevention of occupational diseases, to be described later in this chapter, are applicable to beryllium exposures. Precautions must be taken also to prevent discharge of the material into the outside atmosphere.

The control of beryllium exposures produced by the destruction of fluorescent tubes containing beryllium phosphors presents a somewhat different problem. A

At the request of the United States Public Health Service, the manufacturers of these tubes discontinued the use of beryllium in the manufacture of fluorescent lamps on June 30, 1949. However, stocks of these lamps manufactured previous to this date will probably be on sale for some time. Hence, great care should be used in the disposal of fluorescent lamps. Health and safety authorities \* recommend that such lamps should not be placed in an incinerator but should be destroyed out of doors. They should be wrapped in heavy cartons or burlap bags, broken under water, placed in the disposal container and dumped on a pile where they are completely covered by other refuse. If broken indoors, they should be handled under effective exhaust ventilation. Persons breaking lamps should never breathe the dust and should protect themselves against cuts.

### CADMIUM

The amount of cadmium used in industrial operations has increased greatly during recent years. Cadmium is used for plating metals, as a constituent of alloys, in printing, and in the manufacture of cadmium chemicals, cadmium vapor lamps, pigment, glass, etc. Cadmium may occur also as a contaminant in zinc smelting and refining.

Two types of acute illness may result from exposure to cadmium. The inhalation of cadmium fumes causes a chemical pneumonitis, and ingestion of cadmium leads to severe gastrointestinal irritation.

Cases of chemical pneumonitis in workers exposed to cadmium fumes have occurred chiefly from the application of heat to cadmium-coated surfaces, such as in cutting or welding cadmium plated pipes, plates, rivets, and other materials. Since the cadmium coating does not differ in appearance from other coatings and since the fumes have no specific odor or other warning properties and cause few, if any, symptoms at the time of exposure, most workers are unaware that they have been exposed to a dangerous substance. The symptoms do not begin to appear until about 4 to 48 hours after the acute exposure. The first symptoms are usually dryness of the throat, cough, headache, vomiting, and a sense of constriction of the chest. About 20 to 36 hours after the exposure, symptoms of pulmonary edema appear with pain in the chest, severe dyspnea, and prostration. Death may result from the pulmonary edema or from subsequent bronchopneumonia. If death does not occur, recovery in man appears to be complete, since subsequent roentgenograms are negative. Recent studies suggest that prolonged inhalation of cadmium dust and fumes may possibly produce a chronic illness characterized by proteinuria and emphysema.

Cadmium poisoning by ingestion has resulted chiefly from the use of cadmium-plated food containers. The symptoms, which appear rapidly, include abdominal cramps, severe nausea and vomiting, mild diarrhea, sweating, and headache. Recovery is complete in about six hours. Slight gastric symptoms have occurred in a few industrial cases, presumably from swallowing cadmium dust.

### CHROMIUM

Industrial exposure to chromium occurs principally in the manufacture of chromium compounds from the ore, in the production and use of chrome pigments.

\* Specific directions may be obtained from any state industrial hygiene unit or from the National Safety Council in Chicago.



in chromium plating, in tanning of leather, in fixing of colors, and in bleaching processes.

It is generally believed, at the present time, that pure metallic chromium, chrome ore (ferrous chromite), and the trivalent chromium compounds are not harmful to the body tissues. On the other hand, the hexavalent compounds, the mono- and dichromates and chromic acid, are extremely irritative and corrosive. The important effects of industrial exposure to these hexavalent compounds are chrome ulcers of the skin; ulceration and perforation of the cartilaginous portion of the nasal septum; chrome eczema and occasionally asthma, which are believed to be allergic manifestations; and under certain conditions, bronchogenic carcinoma. Perforation of the nasal septum does not interfere with respiration and is not disabling. Marked gastric irritation may result from the ingestion of chromates, but this condition does not seem to occur in industrial workers, probably because the dust precipitated on the upper respiratory tract does not reach the stomach in sufficient quantity or in its original form. Although damage to the kidneys and other organs has been produced experimentally in animals, no systemic toxic reactions have been proved for men exposed to chromium or to its compounds in industry.

The most serious health hazard of the chromates is due to their carcinogenic property. Cancer of the respiratory tract, chiefly bronchogenic carcinoma, has occurred frequently among men employed in the chromate-producing industry of the United States and Germany and in a few men employed in the chrome pigment industry in Germany. Statistical studies in this country indicate that the incidence of bronchogenic carcinoma is significantly higher in the chromate-producing industry than in comparable control groups. There are no data at the present time to indicate that persons exposed to chromates in other occupations are more than normally liable to cancer of the respiratory tract or that the incidence of cancer in other tissues is excessively high in chromate workers. It is believed that the hexavalent chromium compounds in the form of dust or mist are responsible for the carcinogenic effects, although definite proof is lacking.

### LEAD

**Extent of Lead Exposures.** From the viewpoint of public health, lead is one of the most important of the metals; first, because it produces serious toxic effects; second, because more industrial workers are exposed to lead and its compounds than to any of the other toxic metals; and third, because lead poisoning occurs in a considerable number of children.

**Incidence of Lead Exposure and Lead Poisoning.** From a survey of representative industrial plants in the United States in 1936-39, the United States Public Health Service estimated that about 783,000 workers were employed in industries where lead or its compounds were used (see Table 31-4). No accurate morbidity or mortality statistics on lead poisoning are available since many cases, both in adults and children, are never recognized as due to lead poisoning. For example, between 1931-1940, 26 per cent of all fatal cases of lead poisoning in the entire United States were reported from a city which had only 0.6 per cent of the population of the United States. Most of these cases were in children. There is no reason to believe that the exposure to lead in this city is greater than in other similar cities. The high rate of lead poisoning in this particular city was undoubtedly due to the fact

that its health department maintains an excellent laboratory service for blood lead analysis and to the fact that the pediatric departments in three of its large hospitals are very alert to this condition. This fact indicates that there is a much higher incidence of lead poisoning, especially in children, than is usually recognized.

**Sources of Lead Exposure.** Industrial exposure to lead occurs in the smelting and refining of lead, in the production of storage batteries, in the manufacture and use of lead paints, in the production of tetraethyl lead, in cable sheathing, and in many other occupations in a large variety of industries.

Nonoccupational cases of lead poisoning in children occur chiefly in the summer and at the age of 12 to 24 months when children are teething. It is thought that the children ingest the lead, probably by chewing on window sills, porch railings, cribs, or toys which have been painted with lead paint. In recent years, new toys, furniture, and other articles manufactured in this country for children have not been painted with lead pigments. However, lead poisoning in children still occurs. Most of these cases occur in families of the lower social economic classes who reside in old houses and who may use any available paint to repaint their homes and furniture. Another possible source of lead in these old houses may be the plaster which falls to the floor from walls painted years ago with lead pigments. Other sources of lead poisoning have been reported. A large number of cases of lead poisoning occurred in Baltimore in 1936 when a number of poor families burned discarded battery cases in their kitchen stoves. A child recently developed lead poisoning from swallowing a lead weight which had been attached to a small toy. Thus, lead from various sources may be responsible for the cases in children.

Nonoccupational cases of lead poisoning in older children and in adults are rare. However, some exposure may result from eating fruit sprayed with lead insecticides; from drinking water conveyed in lead pipes, if the water is fairly acid in reaction and has remained for some time in contact with the pipes; from excessive use of colored chalks containing lead; from home production of alcoholic beverages in utensils glazed with lead; and from other such conditions. The use of gasoline containing tetraethyl lead in automobiles presents no hazard to the operator, nor, in fact, to persons dispensing such gasoline at the modern service stations. On the other hand, hazards do exist in the manufacture of tetraethyl lead, in the mixing of it with gasoline, and in the cleaning of the storage tanks. Burning of leaded gasoline in cook stoves, home cleaning of articles with leaded gasoline, and other such exposures also may be very dangerous.

**Relative Toxicity of Lead and Its Compounds.** All lead compounds may be toxic under some circumstances, but some appear to be more harmful than others. The relative toxicity of the various lead compounds has been investigated experimentally in animals by Fairhall and others (1940). Their results indicated that lead arsenate, lead carbonate, and lead monoxide are the most toxic of the lead compounds and that lead sulfide is the least toxic.

**Absorption, Storage, and Elimination of Lead.** In industrial exposures, lead is absorbed in the form of dusts or fumes chiefly through the lungs, and to a small extent, through the alimentary tract. Only organic compounds such as tetraethyl lead are absorbed through the skin. Lead is stored mainly in the bones. Aub, together with his associates (1925), believes that certain metabolic changes in the body subsequently may release the lead which is stored in the bones into the blood stream and thus precipitate an acute attack even though the exposure has



ceased. Kehoe (1947) believes that acute attacks can occur some time after the end of exposure but attributes this poisoning to continuous high levels of lead in the blood which may exist for months after the exposure has ceased. Lead which is stored in the body is slowly excreted after removal from exposure. Excretion may be increased by treatment with the chelating agent, calcium disodium ethylene diamine tetra-acetate (EDTA). Calcium, phosphorus, and vitamin D play a role in the absorption, storage, and mobilization of lead.

**Toxic Effects of Lead.** The toxic properties of lead are believed to be due to an excessive concentration of free lead ions in the circulating blood. It is believed that low concentrations of lead in the blood which cause no toxic symptoms are not harmful to health (Kehoe, 1949).

In general, three types of lead poisoning may result from excessive exposures to lead. The alimentary type, with abdominal colic, constipation, and nausea as the principal symptoms, is the most common type occurring in industrial workers. More severe exposure may lead to the neuromuscular type in which the weakness and paralysis of the extensor muscles of the forearm and other neuromotor symptoms are present. The third type, lead encephalopathy, is rare in industrial cases but is the prevalent type in children. In tetraethyl lead poisoning, nervous symptoms predominate. Lead also causes changes in the red blood cells leading to hypochromic anemia with an increase in reticulocytes and stippled cells. A lead line in the gum margin may occur if hydrogen sulfide, produced by bacterial invasion, is combined with an elevation of lead in the tissues.

Lead poisoning in adults is not usually fatal. The disease is much more serious in children, not only because death results in about 10 per cent of the cases, but because permanent mental damage is reported to occur.

Diagnosis of occupational lead poisoning should be based on the clinical picture, a history of significant lead exposure, and corroborative laboratory findings. The latter should include analyses for lead in the blood and or urine, analysis for urine coproporphyrin and examination of the blood picture. The diagnosis should never be made on the basis of the laboratory findings alone, since these vary with many factors.

**Safe Concentrations of Lead.** Attempts have been made to determine the safe limits of lead exposure for normal persons both in terms of lead intake and in terms of the concentration of lead in the blood and urine. The normal quantity of lead found in the air, food, and water and the highest concentrations which are believed to be safe for the average person are presented in Table 32-4.

Table 32-5 gives the concentration of lead in blood, urine and feces which are believed to represent the safe upper limits for adults. This table also includes the levels which are found in normal persons and in persons with lead exposures of various degrees. Analysis of lead in the feces yields information only on the extent of lead intake immediately preceding the date of collection of the sample.

The blood concentrations in children are somewhat different from those for adults. Clinical symptoms of lead poisoning in children are usually associated with blood lead levels above 0.1 mg. lead per 100 grams of blood. The majority of cases show lead levels between 0.1 and 0.3 mg., with the fatal cases usually between 0.4 and 0.6 mg. per 100 grams of blood.

Safe lead exposures also have been set in terms of the number of stippled red

Table 32-4. Normal and maximum safe lead exposures in air, water and food

Material	Average Normal Exposures	Upper Safe Limits of Exposure
Air	0.05 mg. Pb per 10 cu. meters (Kehoe, 1947)	1.5 mg. Pb per 10 cu. meters air for 8 hrs. per day (Am. Pub. Health A., 1943)
Water	0.02-0.03 mg. Pb per liter water (Kehoe, 1947)	0.1 parts per million or 0.1 mg. Pb. per liter water (USPHS, 1946)
Fruit		0.05 grains metallic Pb per lb. of fruit or 7.1 parts per million as spray residue only on apples and pears (U.S. Food and Drug Adminis., 1940)
Food and drink	0.03 mg. Pb per day (Kehoe, 1947)	0.5 to 0.6 mg. soluble Pb per day (Kehoe, 1943) or even 1 mg. per day (Kehoe, 1940)

cells found in the blood. The normal values, the safe limits, and the number found with lead absorption are given in Table 32-5.

It should be noted that none of the biological criteria of safety listed in the table is infallible, either by itself or in individual cases. In fact, great caution must be observed in the interpretation of such laboratory data. The value in all cases varies with the particular individual, with the extent and duration of the exposure, and with the time at which the samples are collected, i.e., whether early in the exposure or some days after removal from the condition. All of these tests are more significant when done on groups of workers and when followed regularly.

**Prevention of Lead Poisoning.** The most important general measures for the prevention of lead poisoning in industry are the elimination or reduction of the exposures by the various engineering and other methods discussed later (see pages 1086 to 1091). If it is not possible to reduce or maintain the concentration of lead in the air at absolutely safe levels, then it becomes necessary to determine if dangerous amounts of lead are being absorbed by the workers. This procedure requires periodic analyses of blood and/or urine for lead, urine coproporphyrin analysis, and blood cell studies, together with a physical examination. If the occupational exposure to lead is serious, these analyses should be made weekly; if moderate, monthly examinations are sufficient. Annual or semiannual examinations are adequate for low grade exposures. Workers who exhibit signs of abnormal lead absorption should be removed from the exposure. It has been recommended that workers exposed to lead might be rotated so that continuous exposure is avoided. Pregnant women and persons with diseases of the blood should not be employed in lead exposures. Avoidance of constipation and adequate drinking of water are recommended to maintain elimination of the toxic ions, but the habit of taking daily cathartics as a preventive measure should not be encouraged. With regard to the use of ascorbic acid or milk in the prevention of lead poisoning, the Committee on Lead Poisoning of the American Public Health Association stated: "In principle, the administration of ascorbic acid in connection with occupational lead exposure may be regarded in the same light as the common practice of promoting the consumption of milk by lead workers. To the extent that industrial workers suffer from general or specific nutritional deficiencies, any procedure which promotes the correction of these deficiencies is good hygienic practice, but . . . there is no adequate evidence that any dietary regimen, other than one based on general nutritional



Table 32-5. Amount of lead in blood, urine and feces, and number of stippled cells in adults, without lead exposure, following lead exposure, and at upper safe limits

Lead in Urine, Expressed in Milligrams of Lead per Liter of Urine	
Normal values	Average 0.03 (range 0.01 to 0.08 for samples of 1 liter or more; 0.005 to 0.12 for spot samples of 50 ml. or more)
Values indicative of occupational exposure to lead	Above 0.12 to 0.15, but usually not over 0.25 or 0.3, with maximum rarely over 0.5 Above 0.5 indicates unusually severe exposure With brief massive exposure 1.0 may occur
Upper safe limits of occupational exposure	Less than 0.1 for average of a group of workers Less than 0.15 for average of an individual worker generally and above 0.2 very occasionally
Lead in Blood, Expressed in Milligrams of Lead per 100 Grams of Whole Blood	
Normal values	Average 0.03; range 0.01 to 0.06
Values indicative of occupational exposure to lead	Above 0.07 indicates exposure With considerable exposure 0.1 to 0.2 is frequently found; 0.2 to 0.3 is occasionally found; above 0.3 is rare Above 1.0 is usually due to contamination
Upper safe limits of occupational exposure	Range 0.05 to 0.07 Average of 0.05 for group of workers, and 0.065 for individual worker
Lead in Feces, Expressed in Milligrams of Lead per Single Fecal Evacuation Representing 24-Hour Sample (Only Indicates Immediate Lead Exposure)	
Normal values	Average 0.33; range 0.1 to over 2.0
Values indicative of occupational exposure to lead	Above 0.5 as average for a group of workers. Average above 1.1 usually associated with lead intoxication
Upper safe limits of occupational exposure	Below 1.1 for a group of workers
Stippled Cells, Expressed as Number per Million Red Blood Cells	
Normal number	Average of 300 to 350; range from a few cells up to 1,500 or even occasionally up to 6,000
Number indicative of occupational exposure to lead	2 to 8 times normal average In lead intoxication, up to 40,000 temporarily with onset of symptoms
Upper safe limits of occupational exposure	800 to 1,000

Compiled from Am. Pub. Health Ass'n, Report Comm. on Lead Poisoning, 1943

principles, is beneficial under conditions of prolonged occupational lead exposure." (Am. Pub. Health Ass'n, 1943.) EDTA should not be used as a prophylactic measure (Kehoe, 1955).

Prevention of lead poisoning in children would seem to lie chiefly in educating the public, particularly the parents of young children. Improved socio-economic standards, including better housing and nutrition, may also aid in eliminating these cases.

#### MANGANESE

Cases of manganese poisoning have occurred principally among men engaged in the mining and crushing of manganese ore and, to a lesser extent, in metallurgy.

cal industries. Manganese is used as an alloy in the iron and steel industry, in the manufacture of dry cells, glass, paints, dyes and various chemicals; and as an oxidizing and bleaching agent in various processes.

The most important pathological changes which result from exposure to manganese compounds are those which occur in the central nervous system. The characteristic lesion is the destruction of the cells of the basal ganglia and other subcortical areas followed by gross scarring and shrinking. Other parts of the central nervous system also may be affected. The symptoms are similar to the Parkinsonian syndrome. The onset is insidious, with languor and sleepiness followed by weakness in the legs. A masklike face, muscular twitching, stiffness, and tremor develop. The patients show a characteristic gait and emotional disturbances.

Although symptoms may develop within the first three months of exposure, somewhat longer exposures are usually required. If the man is removed from the exposure early in the disease, the symptoms may regress; but well-established manganese poisoning usually leads to permanent total disability without shortening the length of life. Elimination of dangerous exposure and immediate removal from exposure of persons with the slightest symptoms are the only procedures for preventing these tragic cases.

Observations on animals and humans indicate that croupous pneumonia or pneumonitis may also result from exposure to manganese dust.

### MERCURY

Exposures to mercury may occur in many widely different industries, such as in the manufacture of electrical equipment, pharmaceutical preparations, amalgams, munitions, antifouling paint, and other materials. Exposure also occurs in chemical industries and scientific research laboratories, where mercury is used as a reagent. Formerly mercury was used in the felt hat industry, but it has been eliminated from this process in this country.

Mercury vaporizes readily even at room temperatures, especially if it is broken up into small globules, which increase the surface area. Vaporization increases rapidly with an increase in temperature. A tiny globule of mercury weighing 2.8 mg., if completely evaporated in a room 10 feet square and 10 feet high, will give a concentration of 0.1 mg. mercury per cubic meter of air, which is considered to be the maximum safe concentration of mercury vapor.

Mercury may be absorbed through the respiratory tract, the skin, and the digestive tract. It is excreted chiefly in the urine. The metal is a severe protoplasmic poison which may cause acute toxic reactions or, more commonly, chronic illness. The onset is insidious. The chief symptoms of mercury poisoning are: inflammation of the mouth and gums, gastro-intestinal irritation, muscular tremors, and psychic disturbances leading to a peculiar shyness and excitability. Kidney damage may occur.

Some of the organic compounds of mercury, such as diethyl mercury, are extremely toxic. On the other hand, mercury fulminate rarely causes systemic poisoning; dermatitis, sensitization, and inflammation of the mouth and eyes are the chief symptoms.

Certain specific preventive measures, in addition to those common to all toxic dusts and vapors, apply to mercury. Because of its peculiar physical properties, mercury is extremely difficult to collect when it is spilled on floors or table where



the possibility of spillage exists, the floors should be covered with a smooth hard finish without cracks and should slope toward a sump into which mercury can be washed. Rough concrete and wooden floors should not be used. Table tops should be smooth and preferably made of stainless steel. They should be fitted with a trough leading into a jar of water. Walls should be smooth and glossy. Cleaning should be done by flooding with water. Pans containing water should be placed in all locations where mercury leaks may occur. Mercury should be stored in tightly closed containers or under water. Vaporization is prevented when mercury is covered with water and is reduced by coating of the surfaces with polysulfides.

### URANIUM

Uranium when absorbed into the body is one of the most toxic elements. Fortunately, it is absorbed only very slightly through the gastro-intestinal tract or the skin. Part of the uranium is deposited in the bone; most is excreted in the urine. Uranium injures or kills the cells lining the renal tubules and, in severe cases, may lead to uremia and death. If the person survives, regeneration of the cells occurs. Injury to the liver and arteries also has been reported.

### METAL FUME FEVER

Metal fume fever is a temporary malady resulting from the inhalation of heavy concentrations of fresh metallic oxide fumes. Zinc and magnesium are chiefly responsible for this condition, although other metallic oxides may initiate this syndrome. The condition appears some hours after the exposure and resembles the typical sensitization reaction to foreign proteins. The usual symptoms are leukocytosis, rise in body temperature with sweating, chills, dryness of the throat, cough, tightness of chest, dyspnea, and general malaise. Complete recovery occurs in 12 to 24 hours. Persons exposed to metallic oxide fumes develop a temporary immunity to this condition. Metal fume fever does not appear to lead to any permanent damage or to predispose to tuberculosis or pneumonia.

Because metal fume fever resembles acute respiratory infections, such as grippe, it has often been mistaken for a respiratory infection.

Metal fume fever occurs most commonly in galvanizing operations and in welding.

### GASES IN THE AIR

For the purpose of this discussion, the gases in the air may be classified into four groups according to their principal effects.

1. *Natural gases* are those which occur normally in the air and which produce no harmful effects in the ordinary concentrations at normal atmospheric pressures; oxygen, nitrogen, and carbon dioxide being the major constituents.
2. *Asphyxiant gases* are those which prevent the tissues from obtaining oxygen, such as carbon monoxide.
3. *Irritant gases* are those which produce inflammatory reactions of the mucous membranes of the upper or lower respiratory tract or the eyes, such as phosphorus, nitrous fumes, sulfur dioxide, chlorine, hydrogen fluoride, ammonia, acrolein, ozone, and a number of others.

4. *Toxic gases* are those which upon absorption act as tissue poisons; examples are: hydrocyanic acid, hydrogen sulfide, carbon disulfide, arsine and nickel carbonyl.

5. *Narcotizing gases* are those which upon absorption produce an anesthetizing effect of greater or lesser degree, such as nitrous oxide and some organic gases.

In this section, carbon monoxide will be discussed in some detail because this gas presents an almost universal hazard in industries, homes, and public places. The irritant gases will be discussed only as a group, since their effects are similar. For details regarding the individual members of this group, reference should be made to texts and scientific journals dealing with these gases. Four of the more important toxic gases will be considered briefly. The narcotizing gases, other than the organic vapors, present no major industrial health or public health problem and hence will not be discussed. The effects of abnormal pressures of the natural gases in the air are discussed in Chapter 27 and will not be reviewed here.

#### THE ASPHYXIAANT GAS: CARBON MONOXIDE

**Sources of Exposure.** Carbon monoxide is produced whenever organic materials are burned in the absence of sufficient oxygen to transform all of the carbon to carbon dioxide, for example, in the incomplete combustion of coal, gasoline, oil, and other carbon-containing materials. It is produced in the explosion of dynamite and nitroglycerine, in conflagrations, in blast furnaces, in internally lubricated compressors, in automobile and airplane engines, and in innumerable other processes. Automobile exhaust gas contains from 5 to 10 per cent or more carbon monoxide. It is reported that water gas may contain as much as 40 per cent carbon monoxide; producer gas, from 20 to 40 per cent; and coal gas, about 5 per cent. Carbon monoxide occurs only as a trace in natural gas, but incomplete combustion of natural gas may yield higher concentrations. Since gasoline, oil, coal or gas is used in practically every industry, home, automobile, airplane, and ship, potential exposures to carbon monoxide exist almost universally. Furthermore, carbon monoxide is almost odorless, tasteless, and nonirritating, so that persons are unaware of its presence. Thus, prevention of carbon monoxide asphyxiation is an important problem in public health.

**Mode of Action of Carbon Monoxide.** The essential effect of exposure to carbon monoxide is anoxia. The affinity of hemoglobin for carbon monoxide is between 200 and 300 times greater than that for oxygen. Hence, when carbon monoxide is present in the air, the hemoglobin combines with the carbon monoxide and is less available for the transportation of oxygen. Furthermore, carbon monoxide forms a more stable compound with hemoglobin than does oxygen and dissociates much more slowly than does oxyhemoglobin. In the tissues where the oxygen tension is low, the presence of carbon monoxide hemoglobin in the blood tends to prevent the dissociation of the oxyhemoglobin which may be present in the blood. The failure of the oxyhemoglobin to dissociate further increases the tissue anoxia and also interferes with the carriage of carbon dioxide to some extent. Other effects of carbon monoxide, especially on the respiratory enzymes in the cells, have been demonstrated in isolated tissues and in lower animals, but it is doubtful if these play any role in man under the usual conditions of carbon monoxide asphyxiation. Thus, until further data are presented, it may be assumed that the re-



sults of exposure to carbon monoxide in man are due entirely to the interference with an adequate supply of oxygen to the cells.

Carbon monoxide is absorbed through the lungs, rapidly at first and then more slowly, until an equilibrium is reached, beyond which further absorption does not occur as long as the concentration of carbon monoxide in the alveolar air remains constant. The rate of absorption and the total amount of carbon monoxide combined with hemoglobin at equilibrium depends on the partial pressures of the oxygen and carbon monoxide in the alveolar air and on the relative affinities of these two gases for hemoglobin. The rate of respiration, insofar as it affects the partial pressure of oxygen and carbon monoxide in the alveoli, influences the rate of absorption but not the maximum amount of carbon monoxide absorbed. The rate of circulation also influences the rate of absorption. Thus, exercise, which increases respiration and circulation, increases the rate of absorption of carbon monoxide as well as the oxygen requirements of the tissues. The rate of elimination of carbon monoxide is much slower than the uptake, but it can be hastened by breathing oxygen in place of air.

It is usually accepted that concentrations of 100 parts of carbon monoxide per million parts of air can be tolerated for eight hours per day without symptoms, and that 400 p.p.m. of carbon monoxide can be endured without injurious effects for one hour. A concentration of 400 p.p.m. of carbon monoxide causes 40 to 45 per cent of the hemoglobin to be combined with carbon monoxide at equilibrium but only between 15 and 20 per cent in one hour. A concentration of 100 p.p.m. causes only about 15 per cent saturation at equilibrium.

**Effects of Acute Exposures.** The clinical symptoms in man which result from the inhalation of carbon monoxide depend on the rapidity with which a given level of carbon monoxide hemoglobin is reached, on the degree of saturation of the hemoglobin with carbon monoxide, and on the duration of the anoxia. With high concentrations of carbon monoxide in the air, sufficient to cause 60 to 80 per cent saturation of the hemoglobin, weakness followed by loss of consciousness may be the only symptoms preceding death. If the carbon monoxide hemoglobin reaches about 35 per cent saturation rapidly and the duration of exposure is less than a half hour, no very marked symptoms may result. However, if the rate of absorption is slower and the duration of exposure is longer, symptoms may occur with saturations of 35 to 40 per cent. These symptoms include headache, first frontal but later occipital; dizziness; nausea; vomiting; and dyspnea on exertion. Mental confusion and even collapse may occur in some cases. With concentrations below 20 per cent carbon monoxide hemoglobin, the symptoms are usually moderate headache, fatigue, or possible faintness.

Complete recovery occurs following carbon monoxide anoxia in the majority of the acute cases. However, the central nervous system is very susceptible to damage by anoxia, and permanent damage to the nervous tissue may result from prolonged anoxia if it is sufficiently severe to cause coma of long duration. Such severe anoxia may result in permanent psychological, motor, or sensory disturbances.

**Effects of Chronic Exposures.** Repeated exposures to low concentrations of carbon monoxide lead to some degree of acclimatization so that higher concentrations can be tolerated with fewer symptoms. In spite of numerous statements in the literature, there is no sound evidence that repeated exposures to low concentrations

tions of carbon monoxide lead to a chronic condition of carbon monoxide poisoning manifested by circulatory, gastro-intestinal or other disturbances. Medical examinations of traffic policemen who had manned the Holland Tunnel in New York for 13 years showed that they were in exceptionally good physical condition for men of their age. These policemen had had daily exposure to the tunnel air which contained an average of 65 to 85 p.p.m. carbon monoxide with a range from 10 to 235 p.p.m. Their blood carbon monoxide hemoglobin had varied from 0.5 to 13.1 per cent.

**Relation of Carbon Monoxide Exposure to Respiratory Infections.** There is no evidence at the present time that acute or chronic exposures to carbon monoxide lowers resistance to infections of the respiratory tract. Although bronchitis and pneumonia may develop following acute asphyxiation due to carbon monoxide when this is accompanied by a prolonged period of unconsciousness, these conditions are usually attributed to circulatory disturbances or to aspiration of vomitus rather than to bacterial invasion. Experiments performed in this laboratory showed that rats exposed for many weeks to smoke containing 10 to 30 p.p.m. of carbon monoxide, and at times to higher concentrations, did not have a significantly lower resistance to lobar pneumonia when inoculated intrabronchially with Type I pneumococci. It has been reported in the literature that exposure of animals to carbon monoxide does not alter their resistance to artificially induced tuberculosis.

**Prevention of Carbon Monoxide Poisoning.** In industry, the general measures described later as suitable for other toxic gases and dusts are applicable for the prevention of carbon monoxide exposures. There are, however, certain precautions for nonindustrial exposures which might be mentioned here. In the home, prevention consists chiefly in the proper installation, maintenance, and operation of gas appliances. The American Gas Association tests and approves practically all types of domestic gas appliances. Flues should be installed on all fuel-burning appliances where carbon monoxide is produced. The proper ratio of air to fuel will prevent the formation of carbon monoxide in most cases.

Garages and automobiles present some special problems in the prevention of carbon monoxide asphyxiation. The concentration of carbon monoxide may rise to dangerous levels in all commercial garages. Either adequate general ventilation should be supplied or local exhaust attachments should be connected to the waste pipes while the cars are idling. Traffic policemen may be exposed to slightly high levels of carbon monoxide in very congested areas. Concentrations of 200 p.p.m. or more have been recorded under some conditions. Since these concentrations can be tolerated with safety for more than an hour, occasional rotation of duty will prevent any harmful effects in these cases. Greater danger lies in the high concentrations of carbon monoxide which, at times, may exist inside of automobiles. Surveys made of cars selected at random showed in one study that 5 per cent of the cars had at least 300 p.p.m. of carbon monoxide, and in another study 3 per cent of the cars had 100 p.p.m. or more of carbon monoxide. One car had a concentration of 600 p.p.m. Since four hours of continuous exposure to 300 p.p.m. would give over 30 per cent saturation of the hemoglobin with carbon monoxide, such exposures might prove dangerous in some persons. Opening of the windows in the cars did not always alleviate the hazard. Prevention consists in the proper adjustment of the engine and exhaust system. One very important precaution must be mentioned in connection with certain types of heaters used in modern automobiles. The air intake for some of these heaters is placed at the front of the



car under the radiator grill. When such a car is parked within four feet behind a running car and the heater in the rear car is operating, the exhaust from the front car is drawn directly into the rear car. With the windows closed, dangerous concentrations of carbon monoxide have been found in the rear car within one minute. Concentrations of carbon monoxide as high as 1,500 p.p.m. have been found within three minutes when only two feet existed between the rear of the first car and the air intake for the second car. More than four feet of space should be allowed between cars under these circumstances.

### THE IRRITANT GASES

The gases which have an irritating action on the mucous membranes of the respiratory tract and eyes are of great importance in industrial hygiene. Although these gases vary in their chemical structure and in their mode of action, their effects are sufficiently alike so that they may be considered as one group.

**Protective Mechanisms of the Body Against Irritant Gases.** The body has a number of defensive mechanisms to protect the tissues, especially the deeper parts of the respiratory tract, from injury by harmful gases. Some of the irritant gases stimulate the sensory fibers in the upper respiratory tract, and reflexly invoke coughing, sneezing, closure of the glottis, constriction of the larynx and bronchi or even temporary inhibition of respiration. The secretions of the eyes and upper respiratory membranes tend to dilute and wash away irritating substances. The irritation of the upper respiratory tract may be so severe as to drive a person out of the exposure before more serious damage can occur. On the other hand, some gases which produce profound damage to the lower respiratory tract produce only slight irritation of the upper respiratory tract. This reaction is characteristic of exposures to phosgene. Still other gases may give warning effects if the concentrations are immediately high but fail to produce noticeable effects if the amount in the air increases gradually.

**Effects of Acute Exposures.** The acute tissue reaction to irritant gases appears to be essentially the same for all gases although the ultimate result differs according to the principal locus of effect. The reaction is essentially an inflammation with edema and swelling of the mucous membranes, desquamation, and bronchial constriction, all of which tend to block the airways. Pulmonary edema results from exposure to some gases. Those gases which exert their effect on the lower respiratory tract, such as phosgene, often cause no very acute reaction at the time of exposure, except possibly some coughing. The workmen may continue at their jobs unaware that they have inhaled a dangerous gas. After a latent period of several hours, headache, nausea, vomiting, substernal pain, and cough begin to develop. These symptoms become acute usually about 12 hours following the exposure. Dyspnea, cyanosis, and other signs of pulmonary edema appear. Death is due to the resulting anoxia or to subsequent infection. The mechanisms responsible for the pulmonary edema are not thoroughly understood at the present time.

If death does not follow, regression of the symptoms and complete recovery occur in the majority of cases, although some persons appear to have permanent aftereffects. Chronic bronchitis, emphysema, atelectasis, bronchiectasis, and bronchial asthma have been reported in a few cases. These findings in human beings have been supported by experiments on animals. Some animals also show fibrosis of the lungs. However, many of the persons who claim continued dis-

ability after single severe gas exposures have no evidences of any organic injury but exhibit chiefly psychoneurotic symptoms.

**Effects of Chronic Exposures.** Repeated exposures to low concentrations of phosgene and mustard gas in one plant were reported to lead to chronic lung disturbances in some cases. Chronic bronchitis, cough, shortness of breath on exertion, and chest pain were described. The condition did not appear to be disabling, except when complicated by a psychoneurotic component. In another industry, where men had been exposed to sulfur dioxide for many years, a high incidence of nasopharyngitis was found. On the other hand, repeated medical and radiological examination of the industrial workers in a large chemical plant showed no lung damage among workers exposed for 10 years to low concentrations of various irritating gases, including phosgene and sulfur dioxide. Probably, differences in the degree of exposure are responsible for the variations in these reports.

**Relation of Irritant Gases to Respiratory Infections.** One of the problems connected with exposures to irritant gases concerns their influence on susceptibility to respiratory infections. One might expect that the inhalation of irritant gases and fumes would lower resistance to acute infections of the respiratory tract, such as colds or pneumonia. The evidence available at the present time indicates that susceptibility to acute respiratory infections is increased when the exposures are sufficiently severe to produce damage to the respiratory mucosa. However, there is no evidence which indicates that susceptibility to infectious agents is increased after recovery or that prolonged inhalation of irritant gases, in low concentrations and without apparent damage to the mucosa, lowers resistance to acute or chronic infections of the respiratory tract. The incidence of colds and pneumonia in men exposed continuously to low concentrations of irritating gases in smelting and refining plants, in zinc and steel plants, in welding operations, in chemical plants and in other operations have been studied. A review of these studies indicated that the rates of acute respiratory infections in the men exposed to the irritant gases were no higher than those of control groups.

There is also no evidence to indicate that exposure to irritant gases affects susceptibility to tuberculosis. According to Gardner (1942), neither acute nor chronic exposures to irritant gases lower resistance to tuberculosis. This view is supported by: (1) studies of the tuberculosis rates of men who were gassed during World War I, (2) experiments on animals exposed to the war gases, (3) industrial records of men exposed for many years to irritant gases, such as chlorine, sulfur dioxide, sulfur trioxide, hydrochloric acid vapors, and phosgene, and (4) laboratory studies on animals exposed to welding fumes. Dr. Gardner who for many years was Director of the Saranac Laboratory for the Study of Tuberculosis stated: "Sufficient evidence has been cited to indicate that the mere presence of an inflammatory reaction in lung tissue does not alter native reaction to the tubercle bacillus by purely mechanical means. There is no proof that local inflammation favors the implantation of tubercle bacilli nor does it necessarily bring about dissemination of infection from a pre-established focus of tuberculosis. The significant factors responsible for the unfavorable course of a tuberculous process are more likely chemical in nature. . . . None of the evidence available at the present time indicates that dusts, other than free silica, either in pure state or as a contaminant of other materials, or any of the more common industrial fumes or gases have specific action in altering susceptibility to tuberculosis." (Gardner, 1942.)



The possible effect of irritant gases on susceptibility to lung cancer also has been discussed. According to Hueper (1942), there is no evidence at the present time that exposure to irritant gases and nonaromatic vapors plays any role in cancer of the upper or lower respiratory tract.

**Sources of Exposure to Irritant Gases.** Exposure to irritating gases occurs in many different industries and, in some cases, outside of industry. Nitrous fumes may be produced in the manufacture of nitric acid, in the nitration of cellulose and other organic materials, in the manufacture of explosives, dyes, lacquers and films, in bleaching processes, in the metal industry, in welding, and in other processes. Combustion of celluloid and nitrocellulose films also produces nitrous fumes. The liberation of these fumes was presumably one of the factors in the Cleveland Clinic disaster. Phosgene was employed as one of the war gases in World War I. It is produced accidentally when chlorinated hydrocarbons, such as carbon tetrachloride, come in contact with a flame, hot metal, or any other source of great heat. Cases of phosgene poisoning have occurred in industry and in other places as a result of this reaction. A number of cases of phosgene poisoning have resulted from the use of pyrene fire extinguishers in confined places. Sulfur dioxide is formed in many industrial processes, such as in the smelting of sulfide-containing ores and in the combustion of coal and fuels containing sulfur. It is used or produced in many chemical industries. It serves as a refrigerant, as a bleaching agent, and as an antioxidant. Exposure to ammonia occurs mainly from breaks in refrigeration lines and in the manufacture of a number of chemicals. Chlorine is used in laundries, in the sterilization of water, and in many chemical processes.

### TOXIC GASES

Hydrogen sulfide, hydrogen cyanide, carbon disulfide, and arsine are the most important of the toxic gases in industry.

**Hydrogen Cyanide.** Hydrogen cyanide is a liquid which volatilizes at a temperature of 73.4° F. It is evolved from all solutions of cyanide salts in which free caustic is not present. However, in spite of the fact that cyanides are used in large quantities in a number of industrial processes, such as plating and metal hardening, industrial poisoning from the cyanides is rare. Fumigation with hydrogen cyanide offers the most dangerous occupational exposure. Hydrogen cyanide is rapidly absorbed through the skin as well as through the lungs. Its principal action is the inhibition of tissue oxidation. The symptoms of cyanide poisoning are those of anoxemia. The cyanide ion is conjugated with sulfur in the body to form nontoxic sulfocyanides which are eliminated in the urine. Strict regulations are essential in the use of this gas for fumigation purposes. Since it is odorless and tasteless, a warning gas must be added. Gas masks do not offer complete protection since lethal amounts may be absorbed through the skin. It remains in the clothing for some time. Public health codes have been formulated which give specific regulations necessary for the use of this gas in fumigation.

**Hydrogen Sulfide.** Hydrogen sulfide is produced by the decomposition of organic materials containing sulfur. Exposure to hydrogen sulfide, therefore, occurs in tanning leather, rendering fats, manufacturing glue, etc. It is produced in mines where sulfide ores exist and is found in wells. It is used in a number of chemical industries, in the petroleum industry, in the viscous rayon industry, and in chemical

laboratories. Hydrogen sulfide is a particularly dangerous gas because it is not only an irritating gas but also is a systemic poison. The irritating properties of hydrogen sulfide may lead to conjunctivitis, dryness of the nose and throat, diffuse bronchial catarrh and, with acute exposures, to pulmonary edema. When absorbed through the lungs (skin absorption does not occur) it exerts an effect on the central nervous system. In mild doses, depression occurs, whereas excitation follows more severe exposures. Death may result from paralysis of the respiratory center. Recovery, when it occurs, appears to be complete. There is one specific precaution to be noted in the case of exposure to hydrogen sulfide. In low concentrations the odor is so offensive that most persons have ample warning of their exposure. On the contrary, very high concentrations apparently fatigue the olfactory apparatus so rapidly that man cannot smell the odor. Such exposures are extremely dangerous.

**Carbon Disulfide.** One of the most toxic substances encountered in industry is carbon disulfide. It is used chiefly in the viscous rayon and chemical industries and somewhat in the rubber industry. It is a liquid at room temperature but becomes a gas at moderately high temperatures. In extremely high concentrations it may exert an exciting effect on the central nervous system followed by unconsciousness and death. Chronic poisoning is characterized by a toxic effect on all nervous structures, leading to degenerative changes. Polyneuritis, with damage to the motor and sensory nerves, is common. Muscular weakness, tremors, and ataxia may result. Marked visual changes due to optic neuritis and atrophy and to fibrosis and spasm of the retinal vessels appear. The mental symptoms are characterized by irritability, loss of memory, insomnia, confusion and, in more serious cases, by psychoses and by symptoms resembling Parkinsonism. Gastro-intestinal disturbances, skin blisters, loss of libido and other phases of the disease may be present.

Exposure to carbon disulfide may be prevented by the general protective measures described later. Medical examinations should be made weekly in order to detect any symptoms at the earliest moment. Since changes in the retina occur early, tests of vision should be included in the periodic physical examinations for the early detection of carbon disulfide poisoning.

## ARSENIC COMPOUNDS

**Arsine.** The most important arsenic compound from the point of view of industrial toxicology is arsine or hydrogen arsenide,  $H_3As$ . This gas is formed by the action of acids on metals containing arsenic and even by the action of water on hot dross containing arsenic. Arsine is frequently produced in unsuspected locations, since many metals (especially lead, copper, zinc, and aluminum), many ores, and sulfuric acid often contain small amounts of arsenic. Recent deaths due to arsine have resulted from wetting tin dross with water, from the use of aluminum for the removal of arsenic in the refining of lead and from the subsequent handling of the dross, and from cleaning and repairing acid tanks. Arsine may be formed also in the smelting of arsenic-containing ores, in electroplating, in galvanizing, in the manufacture of storage batteries, in pickling operations, in the manufacture of some chemicals, and in a number of other processes.

Arsine is one of the most dangerous gases since it has no warning properties. and, therefore, persons exposed to it may be completely unaware of the presence of this toxic substance. Following exposure, after a short latent period, headache,



nausea, and vomiting occur. Within a day, blood appears in the urine, and in severe cases anuria may occur. Jaundice appears, followed by swelling of the liver and spleen, anemia, kidney damage and pulmonary edema. The symptoms are due to massive destruction of the red blood cells and to the resulting anemia.

**Arsenic Dusts and Fumes.** Exposure to dusts and fumes of arsenic compounds occurs in the manufacture and use of arsenical insecticides, in the refining and smelting of arsenical ores or metals containing arsenic, in the manufacture of glass, and in other industries. The principal effects of industrial exposure to arsenic dusts and fumes (chiefly the oxides and chlorides) are severe dermatitis, conjunctivitis, perforation of the nasal septum, and inflammation of the upper respiratory tract. Chronic systemic poisoning of occupational origin does not appear to be very common. Symptoms of gastro-intestinal irritation and damage to the nervous system are characteristic of arsenic poisoning.

It is generally believed that arsenic compounds can produce skin cancer. Whether such cases can result from skin contact alone or whether the arsenic must first be absorbed or injected into the body is not clear. The possibility that arsenic compounds may cause lung cancer has been suggested by some studies, but convincing proof for this is lacking at the present time.

The use of arsenical insecticides, although potentially dangerous, appears to present only a minor public health problem at the present time. Recently the Division of Industrial Hygiene of the United States Public Health Service (Neal and others, 1941) studied the effects of lead arsenate exposure on orchardists and consumers of sprayed fruits. Among 1,231 persons so exposed, only six men and one woman had a combination of clinical and laboratory findings which could be interpreted as possibly a minimum lead arsenate intoxication.

The spray residue tolerance for arsenic, expressed as arsenic trioxide, on apples and pears has been set at 0.025 grains per pound of fruit by the Food and Drug Administration.

## FLUORINE COMPOUNDS

Fluorides are used in the smelting of beryllium and many other metals, in the refining of aluminum, in the manufacture of steel, in magnesium founding, and in ceramic, glass, enamel, chemical, and petroleum industries. The fluorides are used as insecticides. Fluorine compounds are liberated in the manufacture of phosphate fertilizers and in the welding of stainless steel where fluoride-coated rods are used.

**Acute Effects in Industrial Workers.** The fluoride ion interferes with certain enzyme systems of the body and acts as a general protoplasmic poison. Ingestion of large amounts of soluble fluorides causes marked gastro-intestinal irritation and acute toxic nephritis. Death may occur. Anhydrous hydrofluoric acid, and even aqueous solutions of hydrofluoric acid, cause severe burns of the skin and eyes. Burns from the former are felt immediately, but those from the latter may not be felt for an hour or more after exposure. These burns are so serious that immediate drenching with water, followed at once by medical attention is essential. Heavy neoprene gloves and goggles should be worn where there is danger of contact with these substances. In addition to the skin effects, the chief danger in industry from acute exposures comes from the inhalation of the gaseous hydrogen fluoride

According to Largent, concentrations of 10 p.p.m. or more cause discomfort. With higher concentrations, irritation of the eyes, skin, and upper respiratory tract increase. The inhalation of fluoride dusts also may cause irritation of the upper respiratory tract.

**Chronic Effects in Industrial Workers.** In adults, prolonged exposure to fluoride dust in industry may lead to changes in the bones. According to Roholm (1937), the process is essentially a generalized osteosclerosis with increasing density and thickening of the bone, narrowing of the medullary cavity, periosteal deposits and calcification of the osseous ligaments. The bone changes are most pronounced in the vertebral column and pelvis. The lesions cause some stiffness and reduction of motility. The teeth may show signs of increased formation of dentine and cement. In the Danish cryolite workers studied by Roholm, the general condition of the workers did not seem to be affected, and no lesions other than the bone changes were found. In a few cases described by Møller and Gudjonsson (1932) serious disability occurred. In this country, an increase in the density of the bones and calcification of the ligaments have been found in some industrial workers who had prolonged exposures to high concentrations, but no severe cases with disability have been reported.

The effects of atmospheric pollution with fluorine compounds is discussed in Chapter 29.

**Allowable Concentrations of Fluorides.** The generally accepted maximal allowable concentration for fluorides in the air is 2.5 mg. per cubic meter of air and for hydrogen fluoride, 3 p.p.m. The quantity of fluorine remaining as insecticidal residue on fruits and vegetables is limited by the Food and Drug Administration to 7 p.p.m. of combined fluorine (Food and Drug Administration, 1955).

## THE ORGANIC COMPOUNDS

**Importance of Organic Compounds in Preventive Medicine.** Among the most important chemicals used in industry today are the organic compounds. Already hundreds of different organic compounds are in use and new ones are being produced constantly. Practically every industrial plant, no matter how small, uses some organic compounds in one form or another. Not only are these found in every industry and in almost every type of gainful occupation, but they are used also in every home. Women have become ill from cleaning their clothes with carbon tetrachloride, babies have been poisoned from wearing diapers labeled with an aniline dye and men have died from methyl chloride poisoning due to breaks in refrigeration systems. Many of the organic compounds in sufficiently high concentration in the air can produce acute illness or death, many of them have chronic toxic effects, most of them can cause skin affections, and some of them are highly inflammable. Because of their wide use and their harmful properties, the organic compounds present an important problem to industrial health personnel and to those interested in preventive medicine.

**Source and Nature of Organic Compounds.** The organic compounds are those chemical substances which contain carbon. They are found in plants and animal tissues, and in materials, such as petroleum and coal, which result from the subsequent decomposition of living substances.

The organic compounds which are obtained from the distillation of petroleum



are composed chiefly of the aliphatic hydrocarbons. The crude products include petroleum ether, gasoline, kerosene, fuel oils, lubricating oils, paraffin, mineral oil, asphaltic pitch and other compounds. The materials obtained from the distillation of coal tar are oils which yield the aromatic hydrocarbons (benzene, toluene, naphthalene and anthracene), the phenols and cresols and a residue of coal-tar pitch. From these basic compounds the various hydrocarbons and their derivatives are prepared.

Some of the aliphatic hydrocarbons are gases such as methane, ethane, ethylene, butylene, acetylene, ethyl chloride, etc. Many of the organic compounds are liquids which volatilize readily at room temperature. Because of their solvent properties these compounds are known as the volatile solvents. Many of the organic compounds are solids at ordinary temperatures.

**Chemical Composition and Toxicity of Commercial Organic Products.** It is very difficult to determine the composition and thus the toxicity of commercial organic products. Most of them are sold under trade names, almost all of them are mixtures or contain impurities, and many of them are so newly developed that the toxic properties are not understood. Thus it becomes very difficult for the consumer, whether this be an industry or a private individual, to determine the composition of the chemical substance and whether or not it is safe for use. Information regarding the toxicity of organic compounds may be obtained in some cases directly from the manufacturer. However, statements that the product is nontoxic, without information regarding the chemical nature of the material, should not be accepted. Even published toxicological reports should be interpreted only by persons familiar with this field. The best sources of information on this subject are the industrial hygiene divisions in the federal and state health departments.

**Occupational and Nonoccupational Exposures.** It is impossible to enumerate the industries where exposure to organic compounds occurs since almost every industry either manufactures these chemicals or uses them for one purpose or another. The types of exposure, however, differ greatly. In those industries where these chemical compounds are produced or used in such a manner that their conservation is important, dangerous exposures occur chiefly as a result of accidental leaks and breaks in the equipment, or when cleaning tanks, or when handling, packing or shipping the materials. The chemical, petroleum, explosive and other such industries fall in this group. In other occupations the organic materials are used as solvents for other materials. In these processes, it is desirable for the solvent to be evaporated as rapidly as possible. Here the exposure is more or less continuous but there is less likelihood of sudden high concentrations in the air. Exposures of this type occur in degreasing of metal parts, in the extraction of fats and oils, in dry cleaning and other operations. Organic compounds also are used as solvents of cellulose, gums and resins, etc., in the rubber, rayon, artificial leather and textile industries, and as solvents for pigments in paints, varnishes and lacquers.

In addition to industries, individual persons employ organic compounds as insecticides, rodenticides, dry-cleaning agents, fuel oils, and motor fuels.

The number of persons who are exposed to organic compounds is not known but some idea of the extent of industrial exposures which existed in 1940 can be obtained from Table 31-4, page 1033.

**Absorption and Elimination of Organic Compounds.** The organic compounds encountered in industry are, like the other chemical substances, absorbed through

the respiratory tract. In addition, many of the organic materials are able to penetrate the intact skin and are absorbed directly through this route. Skin absorption is especially characteristic of the nitro and amino derivatives of the aromatic hydrocarbons, such as nitrobenzene, aniline and TNT. Among the other organic compounds which may be absorbed through the skin are phenol, nitroglycerine, tetraethyl lead and methanol and, to a much less extent, the chlorinated hydrocarbons and benzene.

The amount of an organic compound which is absorbed depends on its volatility, on the extent and duration of the exposure, and on its solubility in the body fluids and tissues. Most of the organic compounds are changed into less toxic compounds in the liver or other tissues and are excreted by the kidneys. Some of the volatile compounds are excreted through the lungs.

**Toxic Effects of Organic Compounds.** It is difficult to discuss the toxic properties of these organic materials since they vary greatly in their effects on the body tissues. Even closely related compounds exhibit great differences both in their degree of toxicity and in their specific type of action in the body. Furthermore, the toxic effects vary greatly depending on the condition of the person. Pre-existing organic disease, metabolic disturbances, diet, alcoholism and other factors affect an individual's susceptibility to the organic compounds. For accurate information, reference must be made to books on industrial toxicology where each compound is discussed individually. However, certain general effects appear to be characteristic of the organic compounds as a whole or of the individual classes.

**GENERAL EFFECTS.** One property which is common to practically all of the organic compounds is their narcotic or anesthetizing effect. Their ability in this respect varies directly with their solubility in fat as compared with that in water. Acute exposures to sufficiently high concentrations of these organic vapors may lead to almost instant unconsciousness and death. Recovery may occur with less intense exposures or upon immediate removal from the dangerous environment. With lower degrees of exposure less severe symptoms are found. Headache, vertigo, nausea and vomiting are common symptoms. Convulsions may occur. A state of excitement may precede the depression. Some authorities believe that low grade exposures, although giving rise to no specific symptoms, may produce sufficient drowsiness to constitute an accident hazard under some conditions.

In addition to the acute narcotic effect of the organic vapors, many of the organic compounds exert specific poisonous effects on the body. These systemic toxic reactions may result from a single intense exposure or, more commonly, from repeated exposure to lower concentrations. The organic compounds, because they are fat solvents, remove the oil from the skin and lead to drying and cracking of the skin often accompanied by secondary infections; many of them also cause specific dermatitis. A number of the organic compounds are irritating to the respiratory tract and eyes. Some of the organic compounds are highly inflammable or explosive. These are the general properties of the organic compounds as a whole. The most characteristic reactions for each of the principal classes of organic compounds are given below.

**EFFECTS OF SPECIFIC GROUPS.** *Aliphatic Hydrocarbons.* The aliphatic hydrocarbons act chiefly on the central nervous system, producing a narcotizing or anesthetizing effect. The symptoms of both acute and chronic exposures are characteristic of this reaction. Some of these compounds are also irritating to the respira-



atory tract. Although chronic toxic effects have been attributed to such mixtures as gasoline, benzine and others, they have not been clearly demonstrated.

*Organic Acids.* Exposures to low concentrations of organic acids are not harmful but severe local irritation of the eyes and respiratory tract may result from higher concentrations, and in extreme cases pulmonary edema may occur.

*Esters, Ethers, Aldehydes and Ketones.* These groups of organic compounds are noted chiefly for their narcotic and irritating properties. There is little evidence that they produce systemic toxic effects as a result of exposures in industry. The aliphatic esters, in fact, are among the least toxic of the organic solvents. The aldehydes have only moderate anesthetizing action but are very irritating, not only to the respiratory tract and eyes, but also to the skin. They also may lead to dermatoses as a result of acquired sensitivity.

*Alcohols.* The alcohols, with the exception of methanol, have a comparatively low toxicity. Their effects following inhalation are similar to those produced from the ingestion of these compounds, being chiefly narcotizing and irritating. Methyl alcohol is an outstanding exception. Its narcotic effect is less but its toxicity is far greater than that of the other alcohols. It is decomposed and eliminated from the body very slowly. The chief symptoms of methyl alcohol intoxication include irritation of the mucous membranes, headache, nausea, vomiting, muscular inco-ordination, dyspnea, colic, dilated pupils, impaired vision, blindness, delirium, coma and death.

Methyl alcohol is used extensively in industry, particularly as the solvent for resins, waxes, plastics, dyes, etc.

*Glycols and Their Esters and Ethers.* The glycols or diatomic alcohols are generally considered relatively nontoxic when the vapors are inhaled but they may be toxic when ingested. Propylene and ethylene glycol, which have been used in the sterilization of air, do not appear to produce any damage even in a saturated state. When ingested, they may be harmful. Diethylene glycol, which was used as the solvent for sulfanilamide on one occasion, caused a large number of deaths. Some of the derivatives of the glycols have caused industrial poisonings. For example, dioxane, the secondary ether of ethylene glycol, has been reported to cause hemorrhagic nephritis, central necrosis of liver, gastro-intestinal disturbances, and irritation to mucous membranes. Ethylene glycol monomethyl ether has produced effects on the central nervous system, the blood and the kidneys in a few persons subjected to high exposures.

*The Chlorinated Hydrocarbons.* The chlorinated hydrocarbons form one of the most important groups of organic compounds from the point of view of industrial hygiene. Not only are they among the most toxic of the organic compounds, but they are extensively used both in and outside of industry. Cases of poisoning are reported frequently and a number of deaths have occurred as a result of exposure to the vapors of these solvents. They are noninflammable and certain members of this group are used as fire extinguishing agents.

In high concentrations they exert an anesthetizing effect leading to rapid death due to respiratory failure. They are also irritating to the eyes and respiratory tract and in some cases cause pulmonary edema. Excessive exposures which do not cause fatal narcosis may lead to acute injury of the liver, kidney and possibly other organs. Repeated exposures to lower concentrations produce similar damage. The central nervous system and red blood cells may also be affected. The

most characteristic changes are fatty degeneration or acute yellow atrophy of the liver with swelling and necrosis of the cells, and severe nephritis which involves primarily the tubules. Headache, gastro-intestinal symptoms, dizziness, bleeding from the membranes, jaundice and uremia are the common symptoms. The member of this group which is the most powerful protoplasmic poison is tetrachloroethane (acetylene tetrachloride). Carbon tetrachloride appears to be slightly less toxic but is much more widely used. Trichloroethylene, ethylene dichloride and propylene dichloride are all less toxic.

Methyl chloride and methyl bromide fall into a special class since they cause severe pulmonary edema. Because methyl bromide is particularly effective in this respect, it is rated one of the most dangerous of the chlorinated hydrocarbons.

One of the dangers which may accompany the use of chlorinated hydrocarbons is the formation of phosgene ( $\text{COCl}_2$ ). This gas, which causes pulmonary edema, is produced when the vapors of halogenated hydrocarbons come in contact with open flames, incandescent materials or other sources of heat. A number of fatalities from the chlorinated hydrocarbons have been attributed to the production of this gas.

Because of its wide usage, carbon tetrachloride merits special attention. A number of cases of severe poisoning by carbon tetrachloride have resulted from exposures which were not connected with the industrial processes. One case of poisoning occurred in a man who put out a fire with a carbon tetrachloride fire extinguisher in a small closed space. In another instance three boys died from cleaning their boat with this material. Several recent cases resulted from the cleaning of personal clothing and other objects at home, where only small amounts of the solvent were used. For the most part industries and individuals are unaware of the extreme danger connected with the use of carbon tetrachloride. At the request of the United States Public Health Service manufacturers have agreed to place warning labels on all shipments of this material or similar volatile chlorinated liquid hydrocarbons in excess of 15 fluid ounces or of mixtures containing 24 per cent or over of these materials. However, even smaller amounts may prove hazardous. A brief summary of the symptoms and treatment of carbon tetrachloride poisoning has been published recently by the Council on Industrial Health of the American Medical Association (1946). Copies of this summary may be obtained from this organization.

In recent years, certain dietary factors have been investigated in connection with the hepatitis which results from some of the chlorinated hydrocarbons. Animal experiments showed that a high fat diet and a low protein diet were unfavorable. Methionine appeared to be of some special significance in the prevention and treatment of acute yellow atrophy of the liver from these compounds, especially if associated with a high protein and low fat diet. Choline also appeared to be of benefit. There is a little clinical evidence which supports these results in experimental animals.

*Nitro and Amino Compounds of the Aliphatic Series.* The nitroparaffins are the most common of the nitro compounds. Their chief action is irritation of the respiratory tract and eyes. The nitrites act on the peripheral blood vessels causing a fall in blood pressure. The nitriles, such as acrylonitrile (vinyl cyanide), are extremely toxic. It is believed that hydrocyanic acid is formed from this compound in the body and that this substance is responsible for the toxic properties.



The amino compounds of the aliphatic hydrocarbons do not seem to be of great importance in industrial hygiene. They exert primarily an irritative effect.

*Aromatic Hydrocarbons and Their Chloride and Hydroxyl Derivatives.* The aromatic hydrocarbons include benzene (benzol), toluene, xylene, naphthalene, anthracene and others. Benzene is by far the most important of these compounds, not only because of its toxicity but also because of its extensive use.

In high concentrations the aromatic hydrocarbons all produce acute narcotizing effects similar to the other organic vapors. With very large doses death may occur within a few minutes.

With chronic exposures, benzene is the most toxic of the aromatic hydrocarbons. The symptoms resulting from repeated exposure to benzene vapor are fatigue, headache, vertigo and gastro-intestinal disturbances. Since benzene damages the blood-forming tissues, the chief findings are changes in the blood picture. During the early stages compensatory hyperplasia of the bone marrow may lead to an increase in the number of red and white blood cells but leukopenia and anemia are characteristic of the later stages. Thrombopenia and possibly damage to the vascular walls are responsible for the hemorrhages under the skin and mucous membranes. Injury to the liver, kidney, nervous system and skin have also been reported.

Toluene and xylene are quite different from benzene in their chronic effects, their principal action being on the central nervous system. Naphthalene and anthracene are irritating to the eyes, respiratory tract and skin.

Benzene (benzol) must not be confused with benzine (petroleum ether) which is largely composed of the aliphatic hydrocarbons, pentanes and hexanes. Benzine has a greater narcotic action than does benzene, but it exerts little, if any, systemic toxic effects. Benzene, on the other hand, is one of the most toxic of the organic compounds.

The chlorinated hydrocarbons of the aromatic series, such as chlorinated naphthalene (halowax), cause acute yellow atrophy of the liver and severe skin conditions.

The most important of the hydroxyl derivatives of the aromatic hydrocarbons is phenol. This compound is a protoplasmic poison. The chief effect is on the central nervous system, especially the higher centers.

*The Aromatic Nitro and Amino Compounds.* The most important members of this group of organic compounds are aniline, mono- and dinitrobenzene, trinitrotoluene (TNT), dinitrophenol and beta-naphthylamine. All of these compounds produce serious toxic or other harmful effects.

The characteristic action of aniline, mono- and dinitrobenzene and related compounds is the formation of methemoglobin leading to marked cyanosis. Fortunately, this is a reversible reaction. Damage to the liver, red blood cells and other tissues have been described, but these appear to be less important. Because of the skin absorption, aniline should never be allowed to remain in contact with the skin. Recently a number of cases of aniline poisoning occurred in babies from wearing diapers freshly stamped with an aniline dye. Trinitrotoluene (TNT) is an extremely toxic material which causes aplastic anemia, damage to the liver leading to acute yellow atrophy, some cyanosis probably due to the formation of methemoglobin and dermatitis. It stains the skin yellow and is readily absorbed through it.

Dinitrophenol and dinitrocresol have a somewhat different action from the characteristic effects of this group. The acute disturbance is the marked increase

in basal metabolism, with increase in oxygen consumption, body temperature, profuse sweating, thirst and exhaustion.

Beta-naphthylamine must be mentioned because there is good evidence that this material is an etiologic agent in the formation of bladder tumors. (See under organic chemical compounds in the production of cancer.)

**Organic Insecticides.** In recent years, a number of organic insecticides of great toxicity to man have been developed. Unless adequate precautions are taken, cases of poisoning or even death may occur in persons employed in the manufacture or compounding of these chemicals, in agricultural workers who apply them, in persons who use these chemicals indiscriminately on their own property, in those who ingest them as spray residues on foods, or in others who come in contact with these materials. Because the general public may be exposed to these insecticides, information on their toxicity and methods of treatment are included in this text.

**TOXICITY OF ORGANIC INSECTICIDES.** Organic insecticides differ greatly in their chemical structure and properties and hence in the type and degree of toxicity they produce. A summary of the currently available information on the more common insecticides is given in Table 32-6. The Public Health Service (April 1955) has listed the following general suggestions for the treatment of persons poisoned by insecticides such as those presented in the table. Medical texts should be consulted for specific therapy.

#### GENERAL SUGGESTIONS FOR TREATMENT

In many cases of poisoning, the nature of the toxic agent is not known. The treatment is, therefore, symptomatic and may include:

1. Emesis and gastric lavage if poison has been taken internally.
2. Evacuation of the gut (avoiding oily laxatives where it is possible that an organic solvent or an halogenated insecticide is involved).
3. Thorough washing of the eyes or body if there has been external contact with the poison—wear rubber gloves while aiding the patient.
4. Supportive therapy. (a) Sedatives. Sodium pentobarbital is preferred for acute poisoning because of its rapidity of action. Phenobarbital is useful in maintaining a prolonged level of sedation in persisting neural hyperexcitability or convulsions.

(b) Stimulants. In treating vascular collapse, substances such as adrenalin should be used only after careful consideration, as they are contraindicated in poisoning by the halogenated hydrocarbon insecticides, even though the patient may be in severe depression or coma.

(c) Transfusions. In patients in extremis or extended syncope, transfusions may be indicated except where pulmonary edema is already present. If blood is not readily available or if dehydration is suspected, 5 per cent glucose or normal saline infusions are indicated.

(d) Oxygen therapy. Conventional oxygen-carbon dioxide mixtures should be administered to patients showing cyanosis or severe respiratory difficulty. Patients with pulmonary edema require oxygen under positive pressure as well as postural drainage and dehydration therapy until the exudate is checked.

It is understood that, if the nature of the toxic agent is known, the physician may be able to use a specific antidote to supplement the general treatment. In any event, the importance of general medical care in cases of poisoning should not be underestimated. Even when a recognized antidote is properly administered, the general care of the patient may do as much or more to insure his survival.

Methods for the prevention of harmful effects of insecticides are similar to the methods recommended on pages 1086 to 1090 for toxic compounds in general.



Table 32-6. Toxicity of common insecticides

COMPOUND	COMMON SYNONYMS AND TRADE NAMES	DANGEROUS ACUTE DOSE (GM.)	LOCAL EFFECTS	LOCUS OF ACTION	SYMPTOMS OF ACUTE POISONING	TREATMENT	TOLER- ANCE FOR RESIDUE ON FOOD P.P.M.
Benzene hexa- chloride	BHC, GBL, HCCl <sub>3</sub> , HCH, etc.	30	Irritation; some sensitization	CNS	Excitation, hyperirritability, loss equilibrium, convulsions, depres- sion	General.* Calcium gluconate	5
Chlordane	Lindane (gamma isomer)	7 to 15					10
	Octa-Klor, 1068, Dowklor, etc.	6 to 60	Irritation	CNS	Hyperexcitability, tremors, con- vulsions, depression	General.*	0.3
DDT	Dicophane, Gesarol, Neocid	30	None	CNS	Nausea, diarrhea, vomiting, nervous tension, paresthesia, diz- ziness, tremors, convulsions, de- pression	General.* Calcium gluconate	7
Demeton	Systox, E-1059	12 to 20		Inhibits cholinesterase	See parathion	General.* Atropin	0.75
Dieldrin (aldrin is chemically related compound)	Compound 497, Octalox	10 mg. kg. Much more toxic than DDT. Acute dermal toxicity		CNS	Headache, vomiting, nausea, diz- ziness, hyperexcitability, convul- sions, epileptic-like seizures. Chronic exposures—loss of appetite and weight	General.*	0.1
Diazinon	Prodan Bulan mixture	Unknown. Toxicity <DDT and> methoxychlor	None	Probably CNS	Probably similar to other chlor- inated hydrocarbons	General.*	
Diazotol	DNOG	2		Increased oxidative metabolism	Fever, sweating, rapid respira- tion, fatal hyperthermia. In cold, abolishes shivering with rapid body cooling	General.* Ice bath, O <sub>2</sub> intravenous saline, thioureacl	

Lethanes	Thiocyanates	28 to 70 of concentrates	Irritation			General *
Malathion	4049	Much less toxic than parathion		Inhibits cholinesterase	Depression, convulsions, dyspnea, cyanosis, respiratory paralysis	8
Methoxychlor		450	Slight irritation	CNS	See parathion	General.* Atropin
Nicotine		0.06	Irritation	Nervous systems	Questionable tremors, depression	14
Parathion	E-605, Compound 3422, Thiophos, Niran, Alkron, etc.	0.012 to 0.02 Acute dermal toxicity	Irritation	Inhibits cholinesterase	Tremors, convulsions, curare-like paralysis	2
					Headache, giddiness, disturbed vision, weakness, nausea, respiratory distress, sweating, miosis, lacrimation, salivation, pulmonary edema, muscular tremors, convulsions	General.* Atropin in large amounts. Medical observation for 24 hr.
Pyrethrins	Pyroicide, Kenya flower	100	None	CNS	Incoordination, tremors, muscular and respiratory paralysis	10
Rotenone		200	Irritation	CNS	Stupor, convulsions, respiratory depression	5
Tetraethyl pyrophosphate	TEPP, TEP, Bladex, Fosvex, Nifos, etc.	.025	Irritation	Inhibits cholinesterase	See parathion	General *
Toxephene	Chlorinated camphene, Compound 3956, Alltex, etc.	2 to 7		CNS	Excitement, epileptic form convulsions, depression, respiratory failure	7

\* The general principles of treatment for insecticide poisoning are given in the text. Table compiled from various sources listed under Insecticides in the text references.



However, since many of the insecticides are rapidly absorbed through the skin either in their natural form or in solutions, great care must be taken that such chemicals do not come into contact with the skin. Furthermore, special precautions are required when these chemicals are sprayed from airplanes, by farm machinery or by hand. Information regarding proper procedures for spraying insecticides can be obtained from the Occupational Health Field Headquarters, U. S. Public Health Service, Cincinnati, Ohio. The labels of the containers in which the insecticides are sold also give precautions regarding the handling of these materials. A 1948 federal law requires that insecticide, fungicide, and rodenticide products sold in interstate commerce be registered with the Secretary of Agriculture and adequately labeled for safety. Tolerances for residues of pesticide chemicals on foods are established under authority of the Federal Food, Drug and Cosmetic Act.

**ORGANIC PHOSPHATE INSECTICIDES.** Because the organic phosphates are new chemicals and are very toxic, these compounds will be discussed somewhat in detail. Much of the information presented here was prepared by a group of authorities on this subject and was published in a report of the Committee on Pesticides to the Council on Pharmacy and Chemistry of the American Medical Association, 1950.

The three important organic phosphate insecticides are tetraethylpyrophosphate (TEPP), hexaethyltetraphosphate (HETP), and Parathion (O,O-diethyl O-p-nitrophenyl thiophosphate). These compounds, which are sold under various trade names, are used principally as poisons for the control of aphids, mites, thrips, and other fruit and vegetable crop insects. Parathion is also used as a fumigant. TEPP and HETP hydrolyze rapidly; therefore, the danger of food contamination is less than in the case of parathion, which is absorbed by plants and may remain toxic for several days. These three chemical insecticides may be absorbed through the skin, respiratory tract, conjunctiva and gastro-intestinal tract. They are powerful poisons, since they are potent inhibitors of the cholinesterase enzymes. The chief manifestations, therefore, resemble those produced by excessive stimulation of the parasympathetic nervous system, central nervous system, and somatic nerves. TEPP and HETP are rapidly detoxified in the body and complete recovery follows a single sublethal dose. Parathion is detoxified much more slowly than the other two compounds. After repeated doses, an irreversible inactivation of part of the enzyme occurs which leads to a cumulative toxic action, especially in the case of parathion. Although TEPP and HETP are more acutely toxic than parathion, the latter is the most dangerous because of its greater stability. The acute effects of these poisons come on rapidly and last 6 to 36 hours. Death usually occurs in 10 hours or less. The symptoms should be treated chiefly with atropine. Although these chemicals have been used only for a few years, over 200 cases of poisonings with some deaths have occurred. About two thirds of the cases have been in agricultural workers and the other third in industrial exposures.

Rigid precautions must be taken in the manufacture and use of these toxic insecticides, particularly by agricultural workers. Within industries, they should be handled in enclosed systems or under adequate exhaust, as described later in this Chapter. Since they can be absorbed through the skin and eyes, personal protective equipment, absolute cleanliness, and careful handling are necessary. Empty drums should be washed with hot 5 per cent caustic soda and punched full of holes to prevent their re-use. Empty bags should be buried or burned. If spillage occurs,

should be absorbed in sawdust and then buried or burned. These chemicals should be sprayed in such a manner that they are carried away from the worker by the wind. Thirty days should be allowed after spraying before harvesting. Workers with any symptoms should report immediately to a physician and tell him the nature of the exposure. Grob (American Medical Association, 1950) recommends that periodic determination be made of the cholinesterase of plasma and red blood cells in persons who are frequently exposed to these substances. Persons showing reduced cholinesterase activity should be removed from all exposure until this activity has returned to normal.

**Organic Chemical Compounds in the Production of Cancer.** A considerable number of organic compounds have been shown to produce tumors when tested on laboratory animals. At the present time, proof of a carcinogenic activity in man is available for only a few of these compounds (Hueper, 1942).

Cancer of the urinary bladder has been reported in a number of workers in the organic dye industry. Although aniline has been mentioned repeatedly as the causative factor in these bladder tumors, the evidence both from industrial studies and from experiments on dogs has shown that the causative agent is beta-naphthylamine and that aniline itself is not carcinogenic. There is some evidence also that benzidine is a factor in bladder cancers. Periodic cystoscopic examination of exposed employees is now recommended for workers exposed to these substances.

Cancer of the skin has been reported to result from exposure to organic compounds in several occupations. In the petroleum industry, cancer of the scrotum has occurred in men who worked as pressmen in the paraffin department. It is thought that the carcinogenic substance is probably an aromatic oil contained as an impurity in the wax. It has been shown recently that the higher boiling fractions of petroleum produced by the catalytic cracking process contain substances which will produce skin cancer in a number of animals. Only the fractions which boil above 700° F exert a carcinogenic action. The chemical nature of the carcinogens is not known but it is believed that these substances belong to the aromatic series. No cancers have developed in workers handling this material. The absence of cases in the workers may be due to the fact that production of petroleum by catalytic cracking is a fairly recent process, or to the excellent preventive program which the oil companies have adopted. Cancer of the scrotum in mule spinners has been known for many years in England. The causative agent appears to be the crude Scottish shale oil used to lubricate the spinning machines. The oil soaks into the clothing of the workers and is then rubbed into the skin. The spindle oils used in America seem to be free from this carcinogenic effect, possibly because of greater refinement. Some of the cutting oils also appear to produce skin cancer. The carcinogenic properties of coal tar and pitch are well known. For example, cancer of the scrotum among chimney sweeps has been recognized for many years as an occupational hazard due to the soot.

## THE OCCUPATIONAL DERMATOSES \*

The term occupational dermatoses includes any abnormality of the skin which is related to the occupation. Numerically, the occupational dermatoses are by far

\* The material presented in this chapter has been derived chiefly from the lectures, scientific papers and the books of Dr. Louis Schwartz, formerly Medical Director, Chief, Dermatology section, Division of Industrial Hygiene, United States Public Health Service.



the most important of the occupational diseases and are responsible for more than half of all occupational disease compensation cases. Although occupational skin conditions may cause considerable loss of time from work, they are not usually sufficiently severe to produce permanent disability.

**Protective Mechanisms of the Skin.** The skin has certain barriers against injury. The cornified cells are quite resistant to most chemicals except the strong alkalis. The secretions of the skin form a protective covering against some chemicals and the pigment and thickness of the outer layers of the skin protect against ultraviolet radiation.

**Factors Predisposing to Occupational Dermatitis.** The occurrence of occupational dermatoses depends primarily on the nature of the causative agent and on the duration of exposure. In addition, there are a number of predisposing factors which influence the onset of these skin lesions. The presence of other skin diseases or lesions impairs the resistance of the skin to occupational substances. Lack of personal cleanliness is an important factor since failure to wash the skin or to remove soiled clothing increases the duration of exposure. The type of skin also plays a role. Persons with oily skins, such as Negroes and brunettes, are more susceptible to the oils and tars, whereas those with dry skin are affected more by the defatting agents such as the organic compounds. Younger persons have more acute dermatoses, whereas older persons have more chronic types. Males have a higher rate than females, probably because women take better care of their skin and seek medical attention sooner. There is more dermatitis in summer than in winter due to the fact that less clothing is worn and to the presence of sweat.

**Causes of Occupational Dermatoses.** The etiological factors responsible for the occupational dermatoses may be grouped into four classes: (1) mechanical and physical factors, (2) primary irritants, (3) sensitizers, and (4) biological agents. Among the mechanical and physical factors are heat and cold, and ultraviolet, x-ray, and other radiations (see Chapters 25 and 26). The biological agents encountered in industry do not differ from those which commonly cause skin affections outside of industry. The primary skin irritants and the sensitizers are of much greater importance industrially than the other two classes; therefore, this discussion will be limited to these factors.

A primary cutaneous irritant is defined as "an agent which will cause dermatitis by direct action on the normal skin at the site of contact if it is permitted to act in sufficient intensity or quantity for a sufficient length of time." (Schwartz and others, 1947.) It may exert a direct chemical or physical action on the skin. It may either form a new chemical compound or abstract some essential constituent from the skin. The primary irritants may act: (1) by dissolving the keratin, such as occurs with alkalis or soaps; (2) by dissolving the fat or cholesterol, as with organic solvents; (3) by dehydrating the tissue, as happens with inorganic acids and anhydrides; (4) by precipitation of the proteins, which occurs with some of the salts of heavy metals; (5) by oxidation of the cells, as with bleaches or chromates; (6) by action as reducing agents, such as with some organic acids; and (7) by a keratogenic action, which occurs with some coal tar and petroleum products. There are a number of primary irritants including the inorganic acids, alkalis, and the irritant metals or their salts, such as arsenic or chromium, and most of the organic compounds.

The second class of chemicals which produces occupational dermatoses are the sensitizers. These are usually defined as: "agents which do not necessarily cause demonstrable cutaneous changes on first contact but may effect such specific changes in the skin that, after five to seven days or more, further contact on the same or other parts of the body will cause dermatitis." (Schwartz and others, 1947.) It should be noted that sensitizers are not primary skin irritants but that some primary skin irritants can cause sensitization. The principal substances which produce sensitization in industrial workers are the synthetic dye intermediates, which are formed in the production of dyes from coal tar; the explosives, such as TNT and tetryl; photo developers; formaldehyde; some insecticides and fungicides; the rosins, synthetic resins and waxes; most plants, such as poison ivy; and cashew nut oil.

**Character of Lesions.** The character of lesions found in the occupational dermatoses are not specific for the particular causative agents. Acute and chronic eczema, folliculitis, acne-form lesions, and epidermal proliferation are common to occupational and nonoccupational skin affections. In occupational dermatoses, the site of the eruption usually appears first on the exposed parts or where friction occurs. Other areas may be affected when dust and fumes penetrate the clothing. Distant parts may be affected in cases of sensitization.

**Diagnosis of Occupational Dermatoses.** It is often difficult to determine whether an occupational exposure is responsible for the dermatitis, or if other factors have caused the condition. In order to answer this problem, the history of the disease and the character of the exposure must be known. If the dermatitis does not antedate the employment, but develops during the course of employment, improves within two months when away from exposure and increases again on re-exposure, the condition is probably of occupational origin if there is a substance capable of producing dermatitis present in the occupational environment. Patch tests, if performed intelligently and properly read and evaluated, are of value in the diagnosis of dermatitis resulting from contact with sensitizing agents. Patch tests are of no value in the case of primary irritants. The location and character of the lesion may also assist in determining the cause of the dermatitis.

**Prevention of Occupational Dermatoses.** Prevention of occupational dermatoses depends first of all on the general measures later described which will eliminate, as far as possible, contact of the workers with the dermatitis-producing agents. Where complete avoidance of contact cannot be obtained, personal protective measures should be utilized. These include protective clothing, protective ointments and personal cleanliness.

Protective clothing should cover every part of the body which is exposed to the irritating or poisonous substance, and should be made of materials which are impervious to the dermatitis-producing agent encountered in the particular exposure. Unfortunately, protective clothing is not always intelligently selected. One industry purchased rubber gloves to be worn when handling an organic compound which was a rubber solvent. Often the gloves or boots are too short or too loose at the top so that the harmful material gets inside and is rubbed into the skin. Protective clothing and, in some cases, underclothing must be supplied and laundered daily by the employer. Contaminated work clothing should never be worn away from the place of work.



Protective ointments of many types are available commercially. Some are resistant to water soluble, others to water insoluble substances, some fill the pores with an innocuous fat to keep the fat solvents from attacking the skin oil, and some contain detoxifying agents. Ointments for protection against ultraviolet rays are also available. When applied to the skin these form a film over the skin which may help to protect the skin. In actual practice, the chief value comes from washing them off, since the harmful materials are removed at the same time.

Personal cleanliness is the best safeguard against occupational dermatitis. If severe skin irritants or poisonous chemicals, which can penetrate the skin, touch the skin surface, they should be removed immediately with water. Adequate washing facilities including showers and soap, which will remove the dirt and chemicals but which will not harm the skin, should be supplied. Much dermatitis has been caused by the use of improper chemicals in cleaning the skin. Where particularly irritating or poisonous materials are used, showers should be required on company time. All of the personal measures recommended to protect workers from the occupational dermatoses are equally important to prevent the absorption of poisonous chemicals through the skin.

Pre-employment and periodic examination are important in the prevention of occupational dermatitis, but pre-employment patch tests are not recommended since they may produce sensitization. Workers should consult the industrial physician at the first sign of skin lesions. Authorities in this field believe that employees with mild reactions should be given protective clothing and allowed to continue at work during treatment, since they may develop an immunity to the irritant. Persons with severe dermatitis, who do not develop immunity, should be removed from their occupations or be transferred to other work.

### GENERAL MEASURES FOR THE PREVENTION OF OCCUPATIONAL DISEASES DUE TO CHEMICAL SUBSTANCES

Measures for the prevention of occupational diseases due to chemical contaminants fall into three groups: environmental control; personal control; and medical control.

Environmental controls, designed to prevent contamination of the air and all contact with the harmful materials, are by far the most important methods for protection against occupational diseases. Personal protective measures, on the whole, are of much less value in preventing occupational diseases but at times may be the only possible methods which can be used. Medical procedures are concerned chiefly with the proper placement of workers and the detection of excessive absorption and early toxic signs. Each of these three types will be discussed in some detail.

**Environmental Control.** Since occupational diseases result chiefly from contamination of the working atmosphere, engineering and other methods which prevent the materials from getting into the air are the most important protective measures.

**SUBSTITUTION OF MATERIALS.** The most desirable procedure to prevent dangerous exposures whenever possible is to eliminate the harmful substances from the process and to substitute materials which are nontoxic. For example, steel shot which does not lead to any known lung diseases, may be substituted for the dan-

erous silica sand in abrasive finishing of metal castings, and the aliphatic hydrocarbons can often be used in degreasing operations in place of the more harmful chlorinated hydrocarbons or benzene (benzol). However, substitution of less toxic materials is often not possible. In the case of the organic compounds, the less toxic material recommended as a substitute may be so inflammable that it may present a greater hazard than the more toxic material.

**TOTAL ENCLOSURE.** The best engineering procedure to prevent contamination of the environment consists of enclosing the harmful material in such a manner that it cannot escape into the air, so-called total enclosure. Examples of this type of equipment are tightly covered vats in chemical plants and closed abrasive blasting cabinets. However, totally enclosed processes are not completely satisfactory since the gases, dusts, or liquids may escape through leaks or breaks. Exposures also occur during the filling, emptying, cleaning, and repairing of the equipment. It is often necessary to supplement these units with exhaust systems.

**LOCAL EXHAUST SYSTEMS.** Local exhaust systems are designed to draw air into an exhaust hood by means of suction. When the hood is properly designed, the air current produced by the suction will draw the dusts and gases into the hood. The contaminating material is carried in the air stream through ducts, either to collecting units or to discharge stacks. Dusts may be collected in gravitation, inertial or cyclone separators, settling chambers, in liquid collectors, or by filtration, electric precipitations, impingement, scrubbing, or supersonic sound. Gases may be washed out of the air or treated chemically to reduce them to inert materials. If dusts or gases are discharged into the atmosphere, care must be taken that they do not contaminate nearby operations or the general atmosphere. The design of exhaust systems requires the services of trained industrial hygiene engineers since practically every system presents specific individual problems.

**GENERAL VENTILATION.** Prevention of excessive contamination of the air may be achieved at times by rapid change of air in the workroom. This may be accomplished by forcing air into the workroom or drawing air out of the room by a general exhaust system. General ventilation is more effective in the case of gases than dusts since air movement merely tends to stir up dust.

**WETTING OF DUSTS.** Wet processes for prevention of air contamination with dust involve the application of water to the dust particles as they are formed. Some dusts wet easily whereas others do not. Water sprays are of little value in eliminating most dusts once they get into the air. The dusty water must be removed before evaporation takes place.

**PROCESS CONTROL.** In some cases the process can be organized so that exposure of the workers is held at a minimum, even when dangerous materials are used. An excellent example of this is the common degreasing operation. If degreasing tanks are properly operated, evaporation of the solvent in the air, and thus the degree of exposure of the workers, can be kept at a minimum. Adequate temperature control, slow removal of the objects, little surface agitation, and protection from air currents are all essential in preventing excessive evaporation. Another example of process control is the elimination of carbon monoxide by the proper adjustment of the fuel-air ratio in stoves, motors, etc.

**ISOLATION AND SEGREGATION OF HARMFUL OPERATION.** When it is not feasible to eliminate dangerous operations, it is sometimes possible to isolate or segregate



them so that workers not directly concerned with these processes are not exposed. For example, chemical operations producing highly toxic materials can be located in a separate building. Not only may hazardous operations be isolated in regard to space, but some processes may be postponed until after the majority of the workers have left the environment.

**GOOD HOUSEKEEPING.** One of the most important measures for preventing contamination of the working area is good housekeeping. There are plants, even today, where waste materials capable of producing fatal diseases have settled on the floors, rafters, and ledges, only to be dispersed into the air by the vibration of machinery or the feet of workmen. There are many plants where the daily cleaning consists solely of stirring up the dust with a dry broom. Considerable contamination can be eliminated by good housekeeping procedures such as vacuum cleaning, use of wetting agents in sweeping, proper collection and disposal of waste materials, and immediate removal of harmful chemicals when spilled on the floor or table.

**PLANT AND EQUIPMENT DESIGN.** Exposures to hazardous substances can be prevented by the proper design of plants and equipment. It is far less expensive to incorporate engineering control features into a plant and equipment in the design stage, than to add them after the plant is built and the machinery is installed. Furthermore, the control measures are more efficient when they are designed as part of the original plan.

**UPKEEP OF CONTROL EQUIPMENT.** Like all mechanical equipment, exhaust systems and other control features should be maintained in good repair.

**PERIODIC ENVIRONMENTAL SURVEYS.** Periodic air analyses are necessary when dangerous substances are used in order to assure safe working conditions.

**Personal Control.** When it is not possible or practical to control the environment in which a person works, personal control measures become necessary. These measures include: personal equipment for protection of the respiratory tract, eyes and skin, personal health habits, and other personal procedures.

**PERSONAL PROTECTIVE EQUIPMENT.** *Respiratory Protective Equipment.* Respiratory protective devices, such as gas masks and respirators, are widely employed in industries because they are cheap and can be purchased easily. In many industries, it is assumed that such devices will offer complete protection from harmful materials in the air, if worn during the entire work shift. In reality, however, these devices should be considered only as temporary measures to be used in cases of emergency, for a short period of work or during an interval while environmental control measures are being installed. They may be recommended in rare circumstances if only a very few men are exposed or if the cost of environmental control measures is absolutely prohibitive. They are not adequate for continuous use day after day and should not be used as a substitute for environmental control measures. Furthermore, workers will not wear respiratory protective devices constantly. Anyone who has ever tried to wear even the most modern respirators soon discovers that they are annoying, hot, and uncomfortable. The workers usually hang them on a hook nearby or around their necks, except when the manager or visitors are inspecting a plant.

Respiratory protective devices are, however, invaluable for emergency use, and in some circumstances, they are the only type of protection which can be used. When they are employed, certain precautions should be taken. The type of device pro-

phased must be suitable for the exposure; the device should fit the employee; it should be kept clean and in good condition; and it should be sterilized before being assigned to another employee. The United States Bureau of Mines has developed a system for testing and approving all types of respiratory devices which are submitted by the manufacturers. The approval, if granted, states the type of substance and the circumstances for which the device is approved. The Bureau of Mines' approval number is stamped on each device. Lists of approved models for each specific exposure are published periodically by the Bureau of Mines and may be obtained free upon request. This system of approval has been an excellent safeguard against the use of inadequate protectors.

The personal protective devices which have been approved by the Bureau of Mines fall into five general types:

**Self-contained breathing apparatus.** This type of equipment supplies oxygen directly to the wearer. Hence, it is suitable for any atmosphere. It can be used only for short periods.

**Gas masks.** The cannister attached to the mask filters out the gases or vapors from the air as it is inspired. Gas mask cannisters must be replaced after two hours or less depending on the concentration of the gas in the air. Cannisters are made for individual gases and for a mixture of gases commonly found in industries. These gas masks are similar to those used for protection against war gases.

**Supplied-air respirators.** These respirators are connected with a hose through which uncontaminated air is supplied to the wearer. In some models the wearer draws air through the hose as he breathes, but in the majority of cases compressed air is supplied. Supplied-air respirators can be used only in limited areas and where an uncontaminated air supply is available. Care must be taken that the compressed air does not contain carbon monoxide, which may be liberated by compressors with an internal lubricating system.

**Dispersoid respirators for dusts, fumes or mists.** These respirators cover only the nose and mouth. They are designed to filter out pneumoconiosis-producing dusts, toxic dusts and fumes, mists, or a combination of the various dispersoids.

**Nonemergency gas respirators or chemical cartridge respirators.** These respirators are approved for respiratory protection in atmospheres not immediately dangerous to life or containing not more than 0.1 per cent organic vapors by volume. The cartridges are similar to the gas mask cannisters which are used for organic vapors but are much smaller in size.

**Eye Protective Equipment.** Wherever there is danger of splashing harmful chemical materials into the eye or the possibility of dust, chips, or other solid particles getting into the eye, protective goggles should be required. Heat-treated goggles, which will withstand sharp blows and pressure, are now available at low cost. Individual lenses can be ground in this type of resistance glass. Eye accidents have been greatly reduced in plants where everyone entering the plant is required to wear goggles.

**Skin Protective Equipment.** Protective clothing and ointments have been discussed in connection with occupational dermatoses.

**PERSONAL HEALTH HABITS AND OTHER PERSONAL PROCEDURES.** Personal cleanliness is one of the most important measures in the prevention of occupational diseases of the skin and in the prevention of systemic poisoning caused by absorp-



tion of chemicals through the skin. Frequent washing of the hands, showers at the end of work shifts, and clean work clothes, including underwear, are necessary in some occupations.

Contamination of the mouth with toxic chemicals, either directly or through the hands, should be avoided. The tragic death of the early radium dial painters was due to their habit of moistening the tips of their brushes with their lips.

Since food or tobacco may become contaminated, it is dangerous to take them into the work room where toxic chemical substances are present. A clean place where workers can eat their lunch is desirable under all circumstances, but is absolutely necessary when harmful materials are present. Adequate nutrition and the avoidance of excessive consumption of alcohol are factors in the prevention of some occupational diseases. Where environmental controls are not possible, reduction in the duration of exposure by rotation of jobs may be a sound procedure for preventing occupational diseases.

**Medical Control.** The medical department of a plant or, in the case of smaller plants, the consultant physician can play a major role in the prevention of occupational diseases as well as in their treatment. A medical program directed toward this objective includes the following functions:

**EXAMINATION OF EMPLOYEES.** Medical examinations of employees, which are made at the time of placement, upon return to work after an illness, and at periodic intervals, are all of value in preventing occupational diseases. By the preplacement examination, a physician can exclude susceptible persons from hazardous exposure, such as tuberculous patients from exposure to silica, anemic patients from exposure to benzol, or those with skin diseases from exposure to skin irritants. Examination at the onset or after a nonoccupational illness are important since they help the physician to determine whether the industrial exposure contributed to the illness. Periodic examinations are the most important medical procedure for preventing occupational diseases, since they aid in detecting early signs of excessive absorption of toxic substances or early symptoms of illness. For example, regular periodic blood studies are used to detect excessive lead absorption, and periodic roentgenograms are made to determine the presence of early silicosis or berylliosis. The frequency and type of periodic examination varies with the character and extent of the exposures. Annual examinations may be sufficient for silica exposures, monthly examinations are necessary in some lead exposures, and daily inspection for methemoglobin may be necessary for aniline or nitrobenzene workers. Early detection and treatment often prevent more serious occupational illness.

**ANALYSIS OF MEDICAL RECORDS.** If the medical personnel keeps complete medical records and analyzes them, they can often spot operations in the plant which are producing hazardous conditions. One medical director maintains a chart of the plant layout on which all cases of injury or illness are marked. When abnormal rates are found in any area, the working conditions are investigated.

**KNOWLEDGE OF PLANT PROCESSES AND MATERIALS.** One function of the plant physician is to be completely familiar with every material used or produced in the plant. He should advise the manager concerning the toxicity, the mode of absorption, the type of effect which may result from excessive exposure to the material, and the maximum concentration in the air which is considered safe. He should also suggest the use of less toxic materials wherever possible. It is well for the physician

physician to receive copies of all orders for new chemicals, so that, if toxic chemicals are ordered, he can warn the plant manager about the hazards which these may present before dangerous exposures occur.

One of the duties of the industrial physician is to inspect regularly all processes in the plant which present occupational disease hazards, especially where cases of occupational diseases may be expected.

**EDUCATIONAL ACTIVITIES.** Another responsibility of the industrial physician is to educate the workers in the care of their health. Most authorities believe that workers should be told when their exposure presents a danger to health since this may lead to greater caution in handling the material. Some authorities, however, believe this procedure is unwise since it may lead to unnecessary worry on the part of the worker. The foremen in a plant should be instructed by the physician to watch for any evidences of harmful effects and to report these at once. All workers should be urged to report at once any early indisposition, skin conditions, foreign bodies in the eye, and other symptoms of injury or illness to the medical department. Workers should be carefully trained to avoid unnecessary exposures.

It is evident from the above discussion that prevention of occupational diseases is a cooperative undertaking requiring the active participation of medical personnel, engineers, and the workers. Of even greater importance, however, is the participation of management. Only when management is willing to back up a sound preventive program can occupational diseases be eliminated from a plant.

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## GENERAL HEALTH OF THE WORKING POPULATION

### SICK ABSENTEEISM IN THE INDUSTRIAL POPULATION AND ITS PREVENTION

Industrial hygiene, according to the modern concept as outlined in Chapter 31, includes not only the prevention of occupational diseases, but also the prevention of nonoccupational illness and the promotion of the health of the working people, insofar as this is possible within industry. In recent years, the extent of absenteeism due to nonoccupational illness and accidents in the employed population has become a matter of concern to industrial managements. A survey of industries, made by the American College of Surgeons in 1938, indicated that the average worker lost almost 10 days annually due to sickness and accidents. Of this lost time, only 0.1 day was attributed to occupational diseases and 0.6 day was due to industrial accidents. Nonoccupational illness and accidents accounted for the remainder of the days lost. Since absenteeism, especially short-term absences, interferes greatly with production, nonoccupational sickness is a major problem to management as well as to health authorities.

In order to prevent nonoccupational illness, it is first necessary to determine the extent and causes of illness in the working population and to determine the various factors which influence this illness. With the exception of the National Health Survey and a few family surveys in local areas, the data on the extent of illness in the adult working population has come chiefly from industrial sickness records. Medical records covering all types of illness now are kept by many of the larger plants, but published data are available only for illnesses causing absenteeism. Unfortunately, statistics on sick-absenteeism have many limitations. However, considerable information regarding the illness of the adult working population may be obtained from industrial records.

**Incidence and Cause of Sick-Absenteeism.** The most accurate statistics on the incidence and causes of sick-absenteeism are obtained from the records of the industrial sick benefit societies. The United States Public Health Service has been collecting and publishing such data for large groups of workers for many years. The most recent figures from this source, an average for the years 1943-1952, are produced in Table 33-1. Unfortunately, these records cover only disabilities lasting eight consecutive days or longer and hence do not give a complete picture. The majority of absences due to sickness are of short duration; one third of the total number last only one day and two thirds last only three days or less. Data which include these shorter absences are not available for groups of employees.



Table 33-1. Annual number of absences per 1,000 persons on account of sickness and non-industrial injuries disabling for 8 consecutive calendar days or longer, by cause; experience of male and female employees in various industries, 1943-52 <sup>1</sup>

	ANNUAL NUMBER OF ABSENCES PER 1,000 PERSONS, 1943-52 <sup>2</sup>	
	Males	Females
Sickness and nonindustrial injuries .....	123.2	262.2
Per cent of female rate .....	47	
Per cent of male rate .....		213
Nonindustrial injuries .....	13.0	17.8
Sickness .....	110.2	244.4
Respiratory diseases .....	43.0	107.8
Tuberculosis of respiratory system .....	.7	.5
Influenza, grippe .....	16.3	35.6
Bronchitis, acute and chronic .....	6.9	11.5
Pneumonia, all forms .....	5.3	4.4
Diseases of pharynx and tonsils .....	4.5	16.4
Other respiratory diseases .....	9.3	39.4
Digestive diseases .....	19.2	32.2
Diseases of stomach except cancer .....	6.2	3.8
Diarrhea and enteritis .....	2.5	7.3
Appendicitis .....	4.0	10.9
Hernia .....	2.7	.7
Other digestive diseases .....	3.8	9.5
Nonrespiratory-nondigestive diseases .....	44.3	99.1
Infectious and parasitic diseases <sup>3</sup> .....	2.9	9.0
Cancer, all sites .....	.7	.7
Rheumatism, acute and chronic .....	4.4	4.7
Neurasthenia and the like .....	1.9	13.1
Neuralgia, neuritis, sciatica .....	2.6	3.0
Other diseases of nervous system .....	1.9	2.6
Diseases of heart .....	4.7	2.3
Diseases of arteries and high blood pressure .....	2.3	1.5
Other diseases of circulatory system .....	4.4	6.7
Nephritis, acute and chronic .....	.4	.4
Other diseases of genitourinary system .....	3.7	23.0
Diseases of skin .....	3.6	5.7
Diseases of organs of movement except diseases of joints .....	3.6	6.9
All other diseases .....	7.2	19.5
Ill-defined and unknown causes .....	3.7	5.3
Average number of persons .....	2,189,728	209,468

<sup>1</sup> Industrial injuries and venereal diseases are not included.<sup>2</sup> Average of 10 annual rates.Exclusive of influenza and grippe, respiratory tuberculosis and venereal disease.  
From Gafafer, W. M. Pub. Health Rep., 68:1052, 1953.

but they have been published by a public utility company periodically over the past 40 years. The last figures which are available for this company cover the years 1947-1951. These data, which are presented in Table 33-2, include the frequency rate, i.e., the annual number of absences lasting one day or longer per 1,000 employees; the disability rate, or the annual number of days lost per person; and the severity rate, which is the average number of days lost per absence.

Table 33-2. Average annual number of absences lasting one calendar day or longer due to sickness and injuries, annual number of days of disability per person, and average number of days per absence, by cause: experience in a public utility, 1947-1951, inclusive \*

Cause (numbers in parentheses are disease title numbers from International List of Causes of Death, 1939)	Frequency (Annual number of absences per 1,000 persons)		Disability (Annual number of days per person)		Severity (Average number of days per absence)	
	Males	Females	Males	Females	Males	Females
All disabilities .....	1,466.8	2,442.5	11.066	11.952	7.54	4.89
Industrial injuries (169-195) .....	87.1	10.3	1.874	.369	21.50	36.00
Nonindustrial injuries (169-195) .....	51.6	81.3	.553	.679	10.73	8.35
Sickness .....	1,328.1	2,350.9	8.639	10.904	6.50	4.64
Respiratory diseases .....	801.8	1,233.7	3.068	4.570	3.83	3.70
Tuberculosis of respiratory system (13) ...	.7	.7	.102	.154	137.10	210.00
Influenza, grippe (33) .....	148.4	163.4	.599	.851	4.04	5.21
Colds, coryza (104a) .....	536.3	801.5	1.377	2.018	2.57	2.52
Bronchitis, acute and chronic (106) .....	17.1	35.2	.234	.482	13.70	13.72
Pneumonia, all forms (107-109) .....	7.1	5.1	.260	.181	36.41	35.29
Diseases of pharynx and tonsils (115b, 115c) .....	65.6	183.5	.242	.618	3.69	3.37
Other respiratory diseases (104b, 105, 110-114) .....	26.6	44.3	.254	.266	9.56	6.00
Digestive diseases .....	295.2	617.6	1.682	2.171	5.70	3.52
Diseases of teeth and gums (115a, 115d) ..	35.6	70.7	.082	.170	2.29	2.41
Diseases of stomach except cancer (117, 118) ..	177.6	391.2	.700	.794	3.94	2.03
Diarrhea and enteritis (120) .....	61.9	123.4	.204	.322	3.30	2.61
Appendicitis (121) .....	5.0	14.3	.167	.419	33.58	29.31
Hernia (122a) .....	6.3	2.2	.297	.060	47.55	27.17
Other digestive diseases (116, 122b-129) ..	8.8	15.8	.232	.406	26.40	25.77
Nonrespiratory-nondigestive diseases .....	199.8	408.8	3.806	3.895	19.05	9.53
Infectious and parasitic diseases (1-12, 14-32, 34-44) .....	24.0	25.3	.199	.283	8.29	11.19
Rheumatism, acute and chronic (58, 59) ..	5.4	7.7	.287	.180	52.77	23.43
Neurasthenia and the like (part of 84d) ...	6.1	24.9	.186	.373	30.49	14.99
Neuralgia, neuritis, sciatica (87b) .....	7.9	15.0	.129	.086	16.38	5.76
Other diseases of nervous system (80-85, 87, except part of 84d, and 87b) .....	9.5	33.7	.304	.233	31.89	6.91
Diseases of organs of vision (88) .....	7.6	22.7	.090	.147	11.79	6.45
Diseases of ears and mastoid process (89) ..	9.2	22.3	.055	.146	6.01	6.52
Diseases of heart and arteries (90-99) ....	13.9	3.3	.932	.139	66.94	42.22
Diseases of circulatory system (100-103) ..	14.5	18.0	.306	.338	21.07	18.82
Diseases of genitourinary system (130-138, part of 139) .....	12.7	19.0	.257	.429	20.21	22.54
Dysmenorrhea (part of 139) .....		110.3		.157		1.42
Diseases of organs of movement except diseases of joints (156b) .....	51.1	16.9	.154	.202	9.24	12.00
Diseases of skin (151-153) .....	16.7	60.4	.368	.386	7.20	6.38
All other diseases (45-57, 60-79, 140-150, 154, 155, 156a, 157, 162) .....	21.2	29.3	.539	.796	25.53	27.16
Undefined and unknown causes (200) .....	31.3	90.8	.083	.268	2.64	2.96

\* The number of days of disability is the number of calendar days from the date disability began to the date of return to work, or to the 372nd day, inclusive.

Number of person-years of exposure: Males, 13,436; females, 2,730.

Reference: Gafafer, W. M., U. S. Public Health Service, Personal Communication, December 1, 1955.



Examination of Tables 33-1 and 33-2 reveals some very interesting facts regarding sick-absenteeism in the working population. First, the frequency and the disability rates of sick-absenteeism are much greater for women than for men for all three of the major disease groups, i.e., the respiratory, the digestive, and the nonrespiratory-nondigestive groups. On the other hand, the severity rate, i.e., the average number of days lost per absence, is much greater for men than for women. In other words, women have more frequent illnesses and lose much more time each year due to sickness, but men have longer illnesses when they are sick. This greater frequency of sick-absenteeism among women occurs for most of the diseases, both acute and chronic, which are common to both sexes. The difference is especially marked for those diseases classified as neurasthenia and the like. The only diseases which occur with considerably greater frequency in men than in women are pneumonia, diseases of the stomach, hernia, and diseases of the heart and arteries. This excess sickness among women has been reported in almost all studies of industrial groups, in surveys of the general population, such as The National Health Survey, and in the records of the Women's Army Corps during World War II.

"The reason for the excess sick-absenteeism among women as compared with that among men is not entirely clear. It would not seem to be due to a difference in sex susceptibility to disease, since the mortality rate for males exceeds that for females at all ages." The excess frequency rate appears to be due, in part, to the fact that women take their minor illnesses more seriously than men, since the average duration of sick-absences is shorter for women than men. "Many persons believe that the excess sick-absenteeism among industrial women is due to the fact that they frequently attempt to do two jobs at once, their work in industry plus their duties at home, which may demand heavy labor, worry, and interference with proper rest." Some women have a less serious attitude toward their work than men and may take time off for minor ailments or report unjustified absences as due to sickness more frequently than men. (Baetjer, 1946.)

The second interesting fact evident from Table 33-2 is the importance of respiratory diseases as a cause of sick-absenteeism. This group of diseases accounts for about 50 per cent of the number of cases each year and also 50 per cent of the annual number of days lost. The respiratory diseases are mostly of short duration with an average lost time per case of about five days. Even when only those absences of more than one week are considered (Table 33-1), the respiratory diseases continue to be the most important group.

On the whole, it seems that men lose an average of about 8 days and women 11 days per person per year due to sick-absenteeism. In general, about 2 to 3 per cent of the male employees and 3 to 4 per cent of the female employees are absent each day because of illness and injuries. However, it must be remembered that these are average figures for a group. Industrial physicians have estimated roughly that about 60 per cent of the sick-absenteeism is attributable to about 15 to 20 per cent of the employees and that many workers lose no time at all through illness.

**Factors Affecting Sick-Absenteeism.** The extent of sick-absenteeism in industry varies with a number of factors, the most apparent being age, season, day of the week, and economic conditions. With regard to age, the incidence of minor respira-

tory diseases decreases with age, whereas the chronic diseases, as would be expected, increase in frequency and duration with age.

Sick-absenteeism is much higher in winter than in summer because of the excess of respiratory infections. Absences due to diseases of the central nervous system and to digestive diseases are reported to be greater in summer. The number of cases of sickness causing absences of eight or more days shows a marked variation according to the day of the week. In one company, about 30 to 40 per cent of the absences begin on Monday and 60 to 70 per cent of them terminate on Monday. This custom of trying to "hold out" until the end of the week to stop work and waiting until the beginning of a week to return to work is quite common. Economic

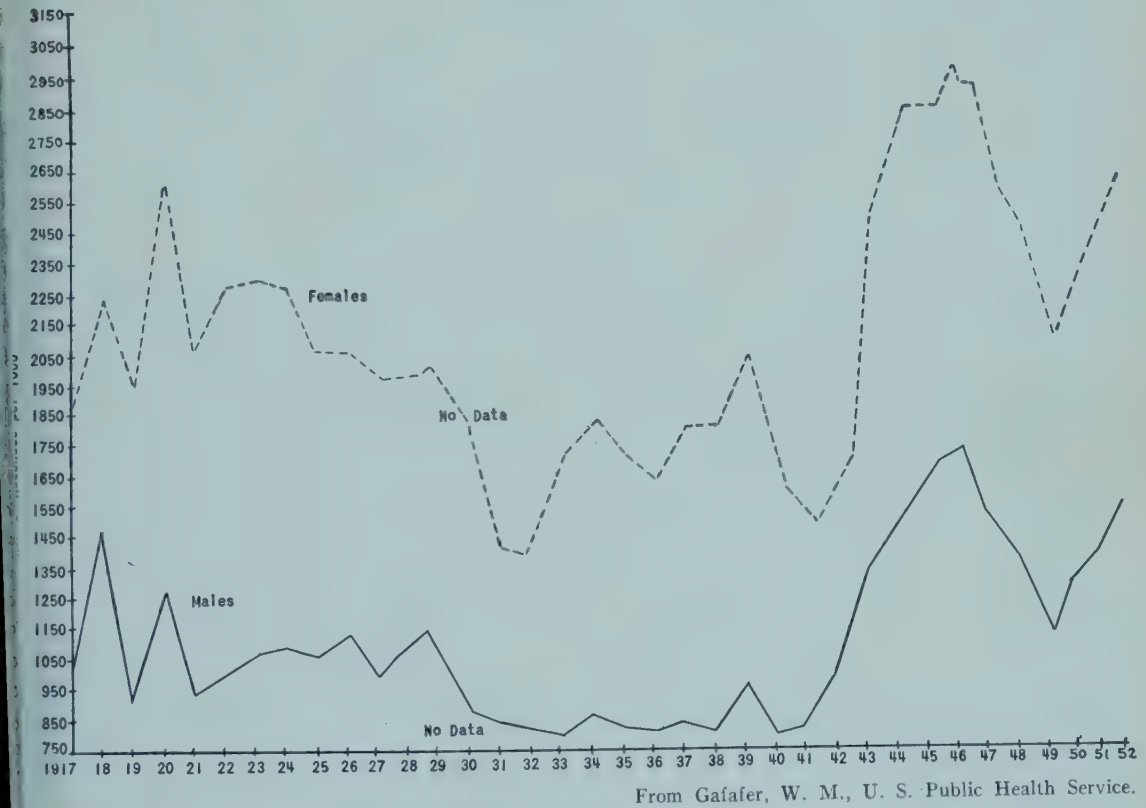


fig. 33-1. Annual number of absences lasting 1 day and longer due to sickness per 1,000 employees, distribution by year.

Factors appear to influence the rate of sick-absenteeism. There is evidence that the greater the sick benefit allowances, the higher the incidence of sick-absenteeism. When payments are made for absences of short duration the frequency of both short and long-term absences appears to increase. In other words, sick-absenteeism is greater when persons can afford to take time off from work. The incidence of sick-absenteeism has shown marked variations over the past 30 years. The trends in sick-absenteeism for cases lasting one day or longer and for cases of eight days and longer are shown in Figures 33-1 and 33-2. These figures show that absenteeism due to illness was low during the years of depression but increased greatly during World War II. This sharp rise may have been due to the employment of persons who were less physically able to work, to the extra work and worry during war time, or to economic factors. The sick-absenteeism rates for men have returned



toward the normal level since the war, but, in the case of women, the rates for absences of eight days and longer have remained excessively high throughout these post-war years. The causes of these continued high rates are not immediately clear.

There are not enough data at present to draw any conclusions about the relation of sick-absenteeism to type of occupation or to hours of work. Also, it is not possible to evaluate the various psychological factors which affect sick-absenteeism rates.



From Gafafer, W. M., U. S. Public Health Service.

Fig. 33-2. Annual number of absences lasting 8 days and longer due to sickness per 1,000 employees, distribution by year.

**Methods of Reducing Sick-Absenteeism.** Although the prevention of non-occupational diseases is not primarily the responsibility of industry, there are many procedures which can be used within industry to reduce sick-absenteeism and to prevent illness. The medical procedures and industrial hygiene programs are described in Chapters 32 and 35. In addition to the work of the medical and industrial hygiene departments, good personnel and management practices undoubtedly affect the incidence of sick-absenteeism. In recent years, it has become evident that the proper selection, placement, training, and supervision of workers is of great importance, not only for efficient plant operation, but also for the health of the workers. A good placement service requires the cooperation of the medical and personnel departments and knowledge of the physical and psychological requirements of the job. In the larger plants, the personnel department should evaluate the ability, background, education, and skill of the applicants, and the medical department

ould judge their physical and emotional fitness. The medical recommendation and e personnel findings should be matched against the job requirements, and each orker should be placed in a job which is compatible with his physical and psy- nological fitness.

The type of supervision is of greatest importance in industrial health. The fore- an has the opportunity to know his men well, so that he can detect early symp- ms of illness. He can often elicit information concerning the social and economic ctors which are leading to worry and sick-absenteeism. On the other hand, poor upervision can lead to discontent, nervous conditions, and even illness. Good lations between employees, and between employees and management, are also mportant factors in the prevention of sick-absenteeism. Persons who are working a good social environment, who are engaged in work which matches their yysical and mental capacity, and who are properly trained and supervised are ss likely to develop those diseases which are influenced by unfavorable psycho- gical factors than are employees who are working under mental stress.

### ACCIDENTS

**General Considerations.** Accidents have now assumed the fourth place as a use of death in the United States. They rank first as a cause of death for the es 1 to 35 years, fourth for the ages 45 to 64 years, and fifth for ages over years. Not only are accidents important because of the large number of deaths ey cause, but also because of the staggering number of persons who are injured. Approximately 90,000 deaths and 9,050,000 injuries are caused annually by acci- ents.\* The distribution of these cases according to the place of occurrence is

Table 33-3. Number of deaths and nonfatal injuries according to principal classes of accidents, United States, 1954

CLASS	NUMBER OF DEATHS	NUMBER OF NONFATAL INJURIES
all classes	90,000	9,050,000
Occupational *	11,200	1,750,000
Public *	15,500	1,950,000
Home *	27,300	4,100,000
Motor vehicle		
Public	33,000	1,150,000
Occupational	2,800	100,000
Home	200	(negligible)
Total motor vehicle	36,000	1,250,000

From Accident Facts, 1955 Edition, National Safety Council, page 3.

\* Exclusive of motor vehicle accidents.

own in Table 33-3. Although motor vehicle accidents are responsible for the atest number of deaths, home accidents cause by far the largest number of uries. The preponderance of home accidents is undoubtedly due to the fact t more man-hours are spent in the home than in any other place. Occupational idents and public accidents, exclusive of those involving motor vehicles, each se less than half as many deaths as home or motor vehicle accidents.

\* Figures based on 1954 data, published 1955 by the National Safety Council.



Table 33-4. Number and rate of deaths according to type of accident, United States, 1954

TYPE OF ACCIDENT	NUMBER OF DEATHS	DEATHS PER
		100,000 POPULATION (adjusted for age)
Motor vehicle	36,000	23.3
Falls	19,900	10.6
Fire burns and other injuries associated with fires	6,300	3.6
Drownings	6,200	3.9
Railroad accidents	2,700	1.7
Firearms	2,200	1.4
Poison gases	1,300	0.8
Poisons—solid or liquid	1,400	0.8
All other types	15,200	8.9

From Accident Facts, 1955 Edition, National Safety Council, pages 6 and 7

Table 33-5. Occupational accidents. Number and rate of deaths and nonfatal injuries according to industrial groups, United States, 1954

INDUSTRY GROUP	KILLED		INJURED	
	Total Number	Rate per 100,000 Workers	Total Number	Rate per 100,000 Workers
All industries	14,000	25	1,850,000	3,240
Mining, quarrying, oil and gas wells	800	107	50,000	6,660
Construction	2,400	74	200,000	6,150
Agriculture	3,800	60	310,000	4,930
Transportation	1,200	41	170,000	5,860
Public utilities	200	14	18,000	1,290
Manufacturing	2,000	12	390,000	2,420
Service	2,300	16	380,000	2,600
Trade	1,300	11	340,000	2,880

From Accident Facts, 1955 Edition, National Safety Council, pages 6 and 7

When the death rates are listed according to the type of accident (Table 33-4), it is evident that motor vehicle accidents rank first, and falls second, as the cause of death. However, this distribution varies somewhat according to age. Motor vehicle accidents rank first at all ages under 65 years; drownings are the next principal cause of accidental death in the age group 5 to 44 years, falls rank second in the age group 65 years and over.

**Occupational Accidents.** The accident rate varies greatly for the different occupations. The number and rates for deaths and injuries due to occupational accidents is shown in Table 33-5 for the principal industrial groups. The most dangerous occupational group is that listed as "mining, quarrying, oil and gas wells." The distribution of occupational accidents according to the source of the injury is shown in Table 33-6. The comparatively low accident rates for many occupations

Table 33-6. Occupational accidents. Per cent distribution of compensable injuries according to source of injury

(Nine State Labor Departments, 1947-1948)

SOURCE OF INJURY	PER CENT OF ALL DISABILITIES DUE TO ACCIDENTS	
	FATAL AND NONFATAL	
Handling objects	22	
Falls	17	
Machinery	16	
Falling objects	13	
Vehicles	7	
Hand tools	7	
Others	18	

From Accident Facts, 1955 Edition, National Safety Council, page 30.

due to the excellent safety programs which are sponsored by the industries. The Workmen's Compensation Laws have been responsible in a large measure for stimulating activity in this field.

Some figures are available to compare the amount of absenteeism from work due to industrial injuries with that due to illness and non-industrial injuries. A study (Accident Facts, 1950) of about 150,000 workers in various industries showed that less than 2 per cent of all absences lasting one day or longer were due to work injuries while approximately 61 per cent were charged to illness and non-industrial injuries. The average number of days of absence due to occupational injuries was 0.6 days per worker per year and 6.5 days for nonindustrial accidents and diseases. Similar figures comparing men and women are given for a public utility company in Table 33-2, page 1097. The injury rates in this company were far lower than the sickness rates. The women employed by this company had higher rates than the men for nonindustrial injuries, but lower rates for industrial injuries.

**Accidents in Public Places.** The number and rate of deaths due to accidents in public places in 1954 is shown in Table 33-7. Motor vehicles are, by far, the most important cause of accidents in this class. When the motor vehicle accidents are analyzed by the death rate per mileage traveled, it is found that more fatal accidents occur in rural areas than in urban areas and more occur at night than during the



Table 33-7. Accidents in public places: number and rate of deaths according to type of accident, United States, 1954

TYPE OF ACCIDENT	NUMBER	DEATHS
	DEATHS	PER 100,000 POPULATION
Motor vehicle	36,000	23.3
Drownings	4,000	2.5
Transportation (other than motor vehicle)	3,500	2.2
Falls	3,100	1.9
Firearms	1,100	0.7
All other	3,800	2.4

From Accident Facts, 1955 Edition, National Safety Council, pages 57, 72 and 73

day. There has been a downward trend in motor vehicle accidents from 1925 to 1954. The number of deaths per 100 million vehicle miles was estimated at between 15 and 20 in 1925, whereas in 1954 it was 6.4. In 1935 approximately 30 out of 100,000 people were killed by motor vehicles. In 1954 the rate was 22.3 out of 100,000. The chief causes of motor vehicle accidents in general is considered to be excess speed, failure to give right of way, driving on the wrong side of the road and driving under the influence of alcohol. A driver or a pedestrian was reported to have been drinking in one out of four fatal accidents. Drivers under 25 years of age seem to have the greatest number of accidents.

**Home Accidents.** The number and rate of deaths according to the type of accident in the home is given in Table 33-8.

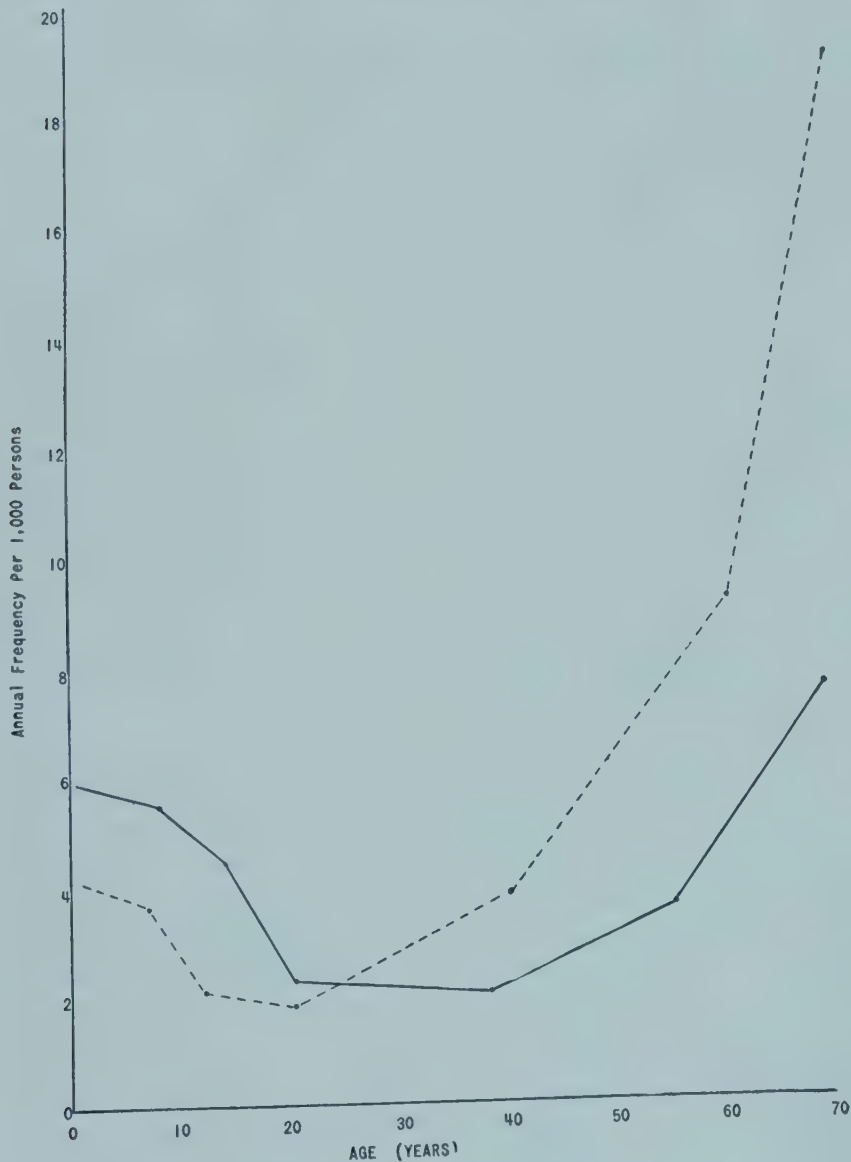
Table 33-8. Home accidents. Number and rate of deaths according to type of accident, United States, 1954

TYPE OF ACCIDENT	NUMBER	DEATHS
	DEATHS	PER 100,000
Total	27,500	17.1
Falls (Principal cause in ages over 45 years)	13,800	8.6
Fire burns and other injuries associated with fire (Principal cause 1-44 years of age)	5,200	3.2
Mechanical suffocation (Principal cause in age group under 1 year)	1,400	0.9
Poisons, solid or liquid	1,150	0.7
Poisonous gas	1,000	0.6
Firearms	1,050	0.7
Other	4,600	2.7

From Accident Facts, 1955 Edition, National Safety Council, pages 86 and 87

The United States Public Health Service made a study of accidents occurring in urban homes as a part of the National Health Survey (Britten and others, 1940). The annual frequency of home accidents disabling for one week or more was 4.65 per 1,000 persons. The distribution by age and sex is shown in Figure 33-3. The annual frequency per 1,000 persons was 2.99 for falls, 0.61 for cutting and piercing instruments and 0.38 for burns. Burns were the chief cause of home accidents.

ents in young children, whereas falls were responsible for most of the accidents in the older ages, especially in women. Persons in poor economic circumstances had more home accidents than did persons in the higher economic income brackets. This was believed to be due in part to poor housing conditions.



Male, ———; Female, ..... .

Fig. 33-3. Annual frequency (per 1,000 persons) of home accidents disabling for 1 week or more, by age and sex. (From Britten, R. H., and others, Pub. Health Rep., 55:2065, 1940.)

**Factors Affecting Accidents. SEX.** There is not sufficient evidence at the present time to state whether women are more or less prone to accidents than men, but experience during World War II did not indicate any greater susceptibility of women to accidents. Differences in rates between men and women appear to be due to differences in exposure.

**AGE AND EXPERIENCE.** Industrial accidents are more frequent among young inexperienced employees than among more experienced workers. Home accidents



are more frequent among older persons. The death rate from motor vehicle accidents is highest in the age group 15-24 years and again at the older ages, 65 years and over.

**FATIGUE AND HOURS OF WORK.** Although fatigue undoubtedly affects accidents, there does not appear to be any relation between frequency of accidents and hours of work except when the hours of work are very long (over 60 per week).

**PERSONALITY.** It has been shown that the majority of accidents occur among a relatively small group of people. There is no doubt that certain persons are more prone to accidents than other persons and that these persons are accident-prone in any occupation. Psychiatrists have studied this problem and have described the personality structure of the accident-prone type as a person who is decisive or even impulsive, a person of action, and not of planning or deliberation.

**PHYSICAL DISABILITY.** The relation of physical disabilities to accidents undoubtedly varies with the type of disability and the circumstances. The disabilities associated with old age must be responsible for the high incidence of falls in the older age groups. However, there is no evidence that physically handicapped persons in industry are especially liable to occupational accidents. The Bureau of Labor Statistics studied this problem in 11,000 impaired workers and 18,000 unimpaired workers. An account of this in "Accident Facts" states: "According to this study, workers with serious physical impairments are no worse accident risks in manufacturing industries than workers without impairments who are performing the same kind of work. . . . In fact, the record of disabling injuries was better for the impaired than the unimpaired workers. No disabling injury to an impaired worker could be traced to his impairment nor were any cases found in which the impairment caused an accident resulting in injury to a fellow worker." (Accident Facts, 1950, page 41.)

**Prevention of Accidents.** In the past, prevention of accidents was not considered a function of public health departments, industrial medical departments, or of any other type of medical personnel. In very recent years, this point of view has changed and public health authorities are beginning to take some part in the prevention of accidents. This would seem to be very desirable, particularly since human failure is the principal or contributing factor in the majority of accidents. Armstrong (1949) has recently discussed the problem of accident prevention: ". . . There is no simple solution to the accident problem, nor can a control program be centered exclusively on any of the various elements involved, such as education, engineering science, and technological progress, or physical status and fitness. Education is certainly important; but educational efforts must be aimed at motivation and as yet we are not quite sure how either children or adults should be motivated to prevent accidents. Engineering science cannot provide the whole answer because many people who are exposed to the same potential accident situations will not suffer any mishap, whereas the 'accident-prone' individual will. We should know why. Again, many feeble and infirm people successfully avoid injury and death from accidents year after year, while more physically robust and healthy individuals suffer repeatedly from accidents. These simple facts alone lead to the belief that there are more deep-seated causes of accidents than senility, poor health, and faulty or unsafe environmental conditions. Probably profound emotional and psychological factors are involved. The fact that in the average experience, a large percentage of accidents occur to a surprisingly small percentage of people should arouse the

curiosity of any health officer. Complex, many-sided, and challenging are the factors which must be taken into account in the field of accident prevention. . . .

" . . . Health departments contain all the elements—the epidemiological experience, the statistical knowledge, the engineering talent, the home and other contacts through the nursing services, and the educational facilities—needed to develop an accident prevention program that, with more information as to etiology, should substantially reduce the number of accidental deaths and permanent disabilities. . . ."

### HEALTH PROBLEMS OF WOMEN IN INDUSTRY \*

The number of gainfully employed women in the United States has been gradually increasing throughout the past century and is now between 18 and 19 million as shown in Figure 31-1, page 1030. Their distribution by occupational and industrial groups is given in Table 31-1, page 1030.

The employment of women creates certain health problems which are associated with their normal physiological processes of pregnancy, menstruation, and the menopause. In addition, there are certain other health aspects, which have been discussed, in connection with the employment of women. These include their strength and ability to work in relation to the type of job, their susceptibility to accidents and occupational diseases as compared with men, and their nonoccupational sickness.

**Relation of Industrial Work to Pregnancy.** When large numbers of women in the younger age groups are employed, the problem of pregnancy in relation to their employment must be considered. In 1953, there were over 12 million women between 14 and 44 years of age who were gainfully employed in the United States. Of this number, about 6,500,000 were married, with husbands present. During World War II, it was estimated that three to six new cases of pregnancy occurred per month per 1,000 women workers. There are no sound data available at present to determine whether the gainful employment of women during pregnancy affects the course of pregnancy, diseases of pregnancy, incidence of spontaneous abortions, premature births or infant death rate. Although some studies on this subject have been published, the results are contradictory and difficult to interpret. Health authorities, in general, believe that it is safe for pregnant women to continue work, at least during the first six months of pregnancy and usually longer, if their health permits and if the character of their work is suitable.

Recommendations concerning the employment of pregnant women have been published by various governmental and private agencies and include the following points: pregnant women should not be employed on work which requires heavy lifting, constant standing, constant moving, or good balance; they should not be exposed to dangerous concentrations of toxic chemical substances, such as lead, mercury, carbon tetrachloride, and others, or to ionizing radiation, since such exposures may exert a harmful effect on the course of pregnancy or on the fetus; and they should not work more than 48 hours per week and preferably not more than 40 hours.

\* The material presented in this section is taken directly from a review of this subject entitled *Women in Industry—Their Health and Efficiency* by A. M. Baetjer, Philadelphia, W. B. Saunders Co., 1946.



It is suggested that pregnant women should cease work at least six weeks prior to delivery and should not return to work until at least six or eight weeks after delivery. These suggested periods are not based on scientific data but represent the current medical opinion. Each case should be handled individually on the recommendation of the woman's physician and under the supervision of the medical department of the plant. Pregnant women should be encouraged to report their condition to the medical department with the understanding that their employment will be continued if their health permits. The policy of dismissing pregnant women as soon as their condition is known or of refusing to hire married women because of the possibility of pregnancy is a very undesirable policy and, at times, may be even dangerous. Under such circumstances, women who desire to work will claim to be single and will hide their pregnancy until their condition becomes obvious, which is usually not until the last half of pregnancy. Since the period of greatest danger from the viewpoint of spontaneous abortion is during the first trimester of pregnancy, it is obvious that these women will continue to work without medical supervision during this period and may be exposed to harmful working conditions. On the other hand, when women are encouraged to report their pregnancies and are assured of continued employment, if their health permits, they can be placed on operations free from harmful conditions if their regular work is not suitable.

The fear on the part of industry that accidental trauma or physical strain encountered in industry might lead to abortions and compensation claims would seem unwarranted in view of the infrequency of abortions due to external trauma and the few compensation claims which have been reported on this basis.

**Relation of Work to Menstruation and the Problem of Dysmenorrhea.** The incidence of dysmenorrhea and the resulting lost time varies greatly in different industries since this condition is affected by psychological factors and is often used as an excuse for other causes of absences. Women engaged in sedentary work have a higher incidence of dysmenorrhea than those engaged in more active occupations. Lost time due to dysmenorrhea can be greatly reduced by certain types of exercises, education, provision of a place for rest and simple first-aid treatment. Statements have been made that exposure to toxic chemicals, heavy muscular work, vibration, constant reaching and stretching may cause or aggravate abnormal menstrual and other gynecological conditions, but proof of this is lacking at the present time. Experimental investigations are greatly needed in this field. "On the basis of the evidence available at present, it would appear that the ability of women to perform mental and muscular work is not altered by the menstrual cycle."

The problems associated with menopausal changes do not appear to be important in most industries at present. Many women suffer no ill effects. Even those who have symptoms of irritability and instability can be employed if their condition is recognized. In fact, it is often desirable for these women to be employed.

**The Ability of Women to Work.** Experience during World War II demonstrated "that properly trained women are capable of performing almost all types of work except those involving excessive muscular work. They are reported to be especially capable at jobs requiring manual dexterity and fine coordination." However, "women are, on the average, only 85 per cent as heavy as men and have only about 60 per cent as much physical strength. Therefore, they cannot lift or hold a

heavy weights, they cannot direct as much weight or strength to the pushing or pulling of loads and their grip is not as strong."

"Women are built on a smaller anatomical scale than men. Their standing and sitting heights, their arm length and size of hands and feet are all smaller. Because of this, machines built to the scale of men often require excessive reaching or stretching on the part of women, and the height of the work bench is often unsuitable. In order to make for maximum production and reduction of fatigue, the machine or the operation should be readjusted to the size and strength of women or else women should be properly selected in relation to the physical requirements of the job."

"Women, like men, vary in size and strength, but no significant correlation exists between weight or height on the one hand and strength on the other. The usual concept of employment personnel, that the heavy women are the strongest, is, therefore, not necessarily correct. The employment of heavy women is of advantage only if they can utilize their weight on their jobs. Heavy women whose weight is chiefly due to adipose tissue may make less desirable employees than thinner women."

"The fact that women are less strong than men does not necessarily imply that they will fatigue more easily except on jobs requiring heavy physical labor. Women may fatigue more rapidly than men but, if true, the rapid onset of fatigue is probably due partly to a lack of background training in industrial work and, chiefly, to the fact that they usually have household duties and responsibilities which require many hours of work in addition to those spent in industry."

"There are no data by which to estimate the incidence of strain and stress injuries among women or to determine whether women are more or less susceptible than men to injuries of the joints, such as tenosynovitis, bursitis, etc. resulting from vibration, friction, or trauma."

**Accidents and Occupational Diseases in Women as Compared with Men.** There is no reliable evidence to indicate that women are any less tolerant to the occupational poisons or occupational dermatoses than are men. There is, therefore, no reason why normal women, who are not pregnant, should be restricted any more than men from working at jobs which involve the use of toxic chemical substances. Under all circumstances the exposures should be kept below harmful levels.

"Women have a much lower rate of industrial accidents than men; especially fatal accidents, but a higher rate of nonindustrial accidents (exclusive of automobile accidents). This distribution is undoubtedly due to a difference in exposure. There is no sufficient evidence at present to state whether women are more or less prone to accidents than men, but experiences during the war did not indicate any greater susceptibility of women to accidents. As in the case of men, certain women appear to be more prone to accidents than others, and the majority of accidents usually occur among a relatively small group of employees."

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# 34

## WORK AND FATIGUE

### INDUSTRIAL FATIGUE

**Nature of Fatigue.** The term "industrial fatigue" is a general expression which is used to describe many different, and often unrelated, conditions of the body. The only characteristics common to the various conditions which are called "industrial fatigue" are a decrease in the output of work and a conscious sensation of tiredness, both resulting from the preceding work. The nature of industrial fatigue is not understood, probably because of the various biochemical, physiological, psychological, and social factors which may contribute to the over-all state of fatigue. The role of these factors will be reviewed.

**BIOCHEMICAL FACTORS IN FATIGUE.** On the basis of fatigue studies on athletes, it was assumed originally that biochemical changes in the blood were responsible for the fatigue which occurs in men performing heavy physical work in industry. Studies of men employed in the iron and steel industry and in other heavy laboring jobs, however, have shown that such work does not lead to an accumulation of acid metabolites in the blood, to oxygen debt, to a fall in blood sugar, nor to an increase of acetone in the urine, which would indicate depletion of carbohydrate. Similarly, biochemical changes have not been demonstrated in the blood of persons engaged in light work requiring repeated coordinated movements. Again, though mental work utilizes carbohydrate material and is very dependent on an adequate oxygen supply, there are no measurable biochemical changes in the blood which account for the fatigue which results from close mental work.

**PHYSIOLOGICAL FACTORS IN FATIGUE.** The majority of industrial operations each day do not require heavy muscular work but rather repeated coordinated movements. Persons engaged in light repetitive work cannot maintain a high speed of production and a normal output indefinitely; their ability to work decreases, and they have a feeling of tiredness or fatigue after working for some time. The fatigue which develops under these circumstances appears to be due primarily to physiological changes in the central nervous system. In any activity involving the repeated use of a nerve pathway over a long period of time, changes may occur in the cell body, the synapse and the nerve ending. It is generally believed that fatigue under such circumstances is first evident in the higher nerve centers. The nature of the changes in the central nervous system are not known. In addition to the fatigue in the nervous system, some muscular changes probably are involved. The physiological changes which result from maintaining a constant posture, as described in the preceding chapter, and from the constant use of the eyes also contribute to the fatigue of industrial workers.



In addition to the physiological changes resulting from work, a number of physiological factors related to the environment also play a role in fatigue. Changes in the circulation and water and salt balance when working at high temperatures, changes in the body resulting from high pressures of nitrogen, and changes in the ear with noise are examples of other physiological factors in fatigue. (See Section 5.)

**PSYCHOLOGICAL FACTORS IN FATIGUE.** In addition to the physiological changes which result from industrial work, there are certain psychological factors, such as boredom, fear, or worry, which are of even greater importance in industrial fatigue. The work may be so monotonous that the output decreases and the worker develops an unpleasant sensation. There are, of course, certain persons who prefer routine and monotonous work and who are able to maintain a high rate of production under these conditions. This situation occurs when the operation becomes almost a reflex act, and the worker can devote his attention to day dreaming or to social conversation with his fellow workers. If, however, the individual devotes his attention to worry over home conditions or to brooding over real or imagined injustices of his work, the output will decrease and the worker will exhibit signs of fatigue. On the other hand, if the work is not monotonous but requires skill and attention beyond the capacity of the worker, here again early signs of a fatigue state may appear.

There is no doubt that fatigue results from mental activity. However, there are no data to indicate the type of alterations in the cerebral cortex which are responsible for this fatigue. In the case of mental work, the degree of interest and other psychological factors determine in a large measure the onset and extent of the resulting fatigue.

The emotional stresses, the constant worry and hurry, the pressure of modern work, the necessity of adjusting to different personalities, the feeling of responsibility, especially in executives, the fear of failure, and the insecurity of many jobs create certain psychological states which constitute the chief factors in the fatigue of many persons. These emotional states have a marked effect on the autonomic nervous system and thus on the fundamental mechanisms of the body and must lead to certain abnormal conditions in gastro-intestinal activity, in the circulatory mechanisms, in the endocrine balance, and in other functions of the body.

**ECONOMIC FACTORS IN FATIGUE.** The economic needs of a worker influence the amount of physical and mental effort which he puts into his work and influence his psychological adjustment to the work; thus, economic factors contribute to the condition of fatigue.

**SOCIAL FACTORS IN FATIGUE.** Industrial fatigue is greatly influenced by the social environment within the plant. The importance of this factor was well demonstrated by the Western Electric Company experiments (Roethlisberger and Dickson 1947). The congeniality of the group working together, the type of supervision, the interest of management, and, especially, the social organization in the plant were found to be the most important factors affecting output and fatigue. Social factors outside of industry also have a marked effect on industrial fatigue.

From the preceding discussion, it would seem probable that fatigue which results from industrial work under normal circumstances is largely due to physiological changes in the nervous system and to psychological factors. Only under certain circumstances do changes in the blood, circulation, water balance, and

Other physiological mechanisms appear to play an important role in industrial fatigue. It is evident from its nature that fatigue may be a normal result of a day's work from which one recovers at night by rest and recreation or that it may be a cumulative state leading to a chronic condition.

There are no adequate methods of measuring industrial fatigue. Because of the many psychological and emotional factors which are involved, the sensation of fatigue is no reliable measure of the changes in the tissues nor is it consistently related to the amount of physical energy previously expended. A person can control his sensation of fatigue and drive himself to continue work, even when exhausted, if the motive is sufficiently great. The work output is decreased in all types of fatigue no matter what mechanism is involved, but because of psychological factors, the capacity to work may not vary in proportion to the amount of previous work and often the output does not indicate the actual capacity to work; it may reflect only a lack of desire to work.

**Prevention of Industrial Fatigue.** The problem of industrial fatigue is one of such complexity that its prevention involves the integration of many factors related to the workers, to the environment, and to the conditions of work. The desirable environment for work is discussed in Section 5. Facts covering the conditions of work are discussed below. In this section, only the conditions which concern the worker will be discussed. Indeed, the psychological and physical conditions of the worker are of greater importance in the prevention of fatigue, than are the conditions of work.

**PSYCHOLOGICAL CONDITIONS.** Since industrial fatigue is affected to such a large extent by psychological factors, the most important measures for the prevention of industrial fatigue are those which concern the psychological state of the workers: the proper placement of employees in relation to their physical and mental capacities, stimulation of interest in the work, provision for some variety in the work, intelligent and understanding supervision, interest of management, job security and financial incentives, a chance for congenial social contacts and group relations, and other similar factors. Such measures are certainly of major importance in the control of industrial fatigue. Since social and economic circumstances outside of industry are often of greater significance in the fatigue of industrial workers than are the conditions at work, the industrial physicians and nurses, counselors and other members of the personnel department should assist in adjusting such conditions when possible.

**PHYSICAL CONDITION OF THE WORKER.** Since many diseases, such as acute respiratory infections, abnormal metabolic conditions, and circulatory disturbances, cause fatigue, the prevention and treatment of these diseases will decrease fatigue in industrial workers. Adequate sleep and recreation are essential in the prevention of fatigue.

Although there is some reason to believe that industrial workers in this country often have faulty diets, there is no convincing evidence at the present time to suggest that malnutrition of the workers in the United States is an important factor in industrial fatigue under normal circumstances. When performing heavy physical work, the total caloric intake should be increased, but the percentage of protein in the diet need not be increased over that recommended for normal requirements. Although prolonged and marked deficiency of some vitamins may lead to fatigue



and weakness, shorter periods of vitamin deficiencies appear to be without any definite effect on the ability to work. Occupations producing unusual physical fatigue do not necessarily demand unusually high vitamin intake. The addition of vitamins to a diet which is already adequate for men doing hard physical work does not appear to improve muscular ability, endurance, resistance to fatigue or recovery from fatigue.

The question of taking food, especially carbohydrate food, between meals has been discussed as a measure for relieving industrial fatigue. Some authorities believe this procedure is generally beneficial, whereas others claim that it is of benefit only in very severe muscular work. The value, if any, of consuming food between meals may be due in part to the rest period and the accompanying change of interest and posture rather than to the food itself.

## METHODS AND CONDITIONS OF WORK

**Methods of Work.** Industrial hygienists are concerned not only with the environment in which a man works but also with the methods of work, with the design of equipment and processes, and with the length and arrangement of the working shifts. Fatigue is decreased, efficiency is greater, and the chances of injury and illness are less when persons are employed at operations which allow normal physiological functioning and which do not place too severe physical or psychological stresses on the body.

Originally, machines and processes were designed without regard to the human element in production, and people did their individual task at any speed or in any manner they preferred within the limits of their equipment. It might be expected that a person would select instinctively the best way of working but this theory is apparently not true. The originators of "time and motion studies" showed dramatically the extent of wasted motion, the inefficiency of many workers, and the improper arrangement of many industrial processes. Although "time and motion studies" have contributed greatly to the efficiency of production, such studies do not indicate necessarily the best method of operation from a physiological point of view.

There have been a few physiological investigations to determine the optimum methods of work, but most of these have been limited to studies of the oxygen consumption and mechanical efficiency of men doing various types of physical work. Although measurements of oxygen consumption give some indication of the desirable methods of doing certain jobs, this procedure is not always advisable. Indeed, an occupation which requires no physical work at all and thus no appreciable increase in oxygen consumption over the basal level may not be physiologically desirable and may even result in loss of muscular strength.

The applied psychologists have contributed more knowledge concerning the proper methods of work than any other group. They have studied the desirable illumination, color, and spacing of objects for rapid vision; the optimum speed and rhythm of work; the best type of coordinated movements for performing specific operations; and many other phases. However, the results of these studies have not been applied to industrial work except in rare instances.

During World War II some physiological and psychological studies and anatomical measurements were made as a basis for the design of airplanes, armored

tanks, radar equipment, etc. At the present time an effort is being made to interest industrial engineers and managers in this problem, so that industrial equipment and processes will be designed to fit the size and the strength of workers and will permit optimum physiological functioning of the workers. The engineering phase of this field is termed "Human Engineering."

**Length and Arrangement of the Working Day.** It is not possible to recommend any general schedule of hours as optimum for the health of workers, because of the great variability in the types and conditions of work, the state of the individual workers, and the many other factors involved. In fact, it is very doubtful if standards for the hours of work will ever be established on a physiological or health basis since this question is so profoundly affected by social, economic and psychological factors. However, there are certain facts regarding the hours of work which are based on sound experience.

During World War I it was found in England that long hours, 70 to 80 or 90 hours per week, could not be tolerated for long periods of time and that the total weekly output was greater if the hours did not exceed about 60 per week. During World War II, following the battle of Dunkirk, the hours of work were increased again to 72 and even 77 per week. Because of the tremendous incentive, the output rose but could not be maintained in spite of the great need for production. After two months the hours again were reduced to 60 per week. All of the available evidence indicates that working hours in manual operations involving a fair amount of physical effort should not exceed 60 to 65 per week for men and 55 to 60 per week for women. Most authorities believe that if a high degree of efficiency is to be achieved, the hours of work should be less than these maximum limits. The general opinion in this country is that 48 hours per week, or 8 hours per day for 6 days, are the maximum hours of work which are desirable, and some people believe that shorter hours of work are advisable, at least under certain conditions. A group of governmental agencies in this country issued a joint recommendation during World War II supporting the 48-hour work week during that period. A number of states also have adopted laws which set the maximum hours of work at this figure.

Increasing the hours of work above 48 per week leads to a decrease in hourly output, although the daily output may rise; but excessively long hours often lead, as shown above, to a reduction in total output. Absenteeism increases progressively with an increase in hours of work. A few studies have indicated that sick absenteeism increased when the hours of work were above 50 per week but it is difficult to evaluate these data because of the many other factors involved. There does not appear to be any relation between accidents and hours of work except when very long hours, over 60 per week, are worked. Women with children or other home responsibilities should work shorter hours than 48 per week.

One day off per week is essential for all workers. If this is not allowed, both the efficiency and total production decrease and absenteeism and accidents increase. Night work does not appear to be much more fatiguing than day work if rest is possible during the off hours and if the hours of work are normal. During World War I the British found no difference in production when the shifts were rotated but some decrease in production in the case of women when the night work was continuous. Some physiologists believe that rotation of shifts is not advisable



because such changes, especially if frequent, interfere with the diurnal physiological rhythms. Since social activities are organized on the assumption of day work, continuous night work often creates dissatisfaction among the employees. Many more studies are needed before it can be said whether night work is or is not physiologically unsatisfactory. Rest pauses in the middle of the morning and afternoon work periods have been shown to be of benefit, especially if there is a change of posture during these periods.

**Effects of Certain Types of Work.** **VIBRATION AND REPEATED MOTION.** Pneumatic vibrating tools, such as grinding and riveting machines, chipping hammers, drills, and other similar tools expose workers to repeated percussion. Large drills used to break rock or paving have a frequency rate of 1,500 to 3,000 blows per minute. Smaller drills and grinders have frequencies of 2,000 to 50,000 blows per minute. The use of such tools may lead to specific occupational diseases, the most common of which is vasospasm or "white fingers." It is generally stated that the rate of vibration is an important factor in the onset of this condition. Tools which give less than 4,000 blows per minute, especially those with 2,000 to 3,000 blows per minute, appear to be the most dangerous. Vasospasm is characterized by the spasmodic contractions of the blood vessels of the fingers which cause the fingers to become temporarily white and numb. The spasms affect chiefly the fingers of the hand which holds or guides the tool, i.e., the left hand. Although these attacks may occur while working in a warm room, they usually come on upon exposure to cold. Upon rewarming, the fingers become pink and severe pain is felt. Between attacks the hand appears normal. If a patient is removed from the exposure soon after the spasms begin, recovery may occur. Once the condition is well established, it does not progress further, but the attacks are likely to continue for many years even after removal from the exposure. The disease does not lead to any changes in the structure of skin, capillaries or arterioles. Vasospasm may appear after a few months of work with a vibrating tool or not until after several years of exposure. Some workers never develop the condition.

Repeated motion may lead to changes in the joints. The most common occupational diseases of this nature are tenosynovitis and bursitis. In tenosynovitis, the repeated use of a tendon or sudden strain on the tendon may lead to rupture of the blood vessels into the tendon sheath. This condition results in pain on exertion. Bursitis, or an inflammation of the synovial mucous membranes which line the various moving surfaces of the body, may result from constant abnormal friction on the tendons, usually at the joint. The movement of the joint becomes limited and painful due to the presence of fluid in the bursa. Pneumatic drills which are held against the shoulder may cause bursitis. Miners who lean continually on their elbows may develop a bursitis of the elbow. Constantly repeated traumatic injuries to the joints may also play a role in degenerative changes of the bones.

Prevention of the harmful effects of vibrating tools may be accomplished by the use of mechanical devices to hold the tool in place of the hand, and in some cases by the use of protective mittens. Nonvibrating tools should be used wherever possible. Early recognition of vasospasm and immediate discontinuation of the work is necessary. Tenosynovitis may be prevented in some cases by the use of rubber pads to prevent constant pressure of joints against hard surfaces, and by changes in posture and methods of work.

**LIFTING AND CARRYING LOADS.** The lifting of loads is a common industrial task which may place severe strain on the body. The usual method of lifting a weight is to bend over at the waist while keeping the legs straight. This method is apt to lead to back strains or hernias. The recommended procedure is to stand close to the object with the feet 8 to 12 inches apart, and to bend the knees rather than the back, so that the strain is placed on the leg muscles. When turning, the workers should shift the position of the feet, rather than twist the body.

The carrying of loads also places certain stresses on the body. Methods which cause displacement of the center of gravity, interference with movement, fixation of the chest, and local strain are not physiologically efficient. The most efficient method is to carry a load equally divided on a yoke from the shoulder; the next best, to carry two equal bundles, one in each hand with arms straight down at the sides. The poorest procedure is to carry loads on one hip. Health authorities are often asked about the maximum loads which should be carried. The Industrial Health Research Board of Great Britain (Cathcart and others, 1927) recommended loads equal to 35 to 40 per cent of the body weight as maximum weights for continuous carriage. Since there is no good correlation between weight and strength, such standards are not very reliable.

**POSTURES AND MOVEMENTS.** Static work is much more fatiguing than dynamic work. When a person stands for a prolonged period of time, there is a tendency, though quite variable among healthy men and women, for the blood to pool in the extremities and the splanchnic area due to the hydrostatic effects of gravity. This stagnation of the blood may lead to extravasation of fluid, swelling of the legs, and, if prolonged, to cerebral anemia. Muscular movement, or even swaying and shifting of position, will assist in counterbalancing this effect and will aid in returning blood to the heart. A constant sitting or bending posture may produce congestion of the pelvic organs and interference with digestion. Improper seats may cause unnecessary energy expenditure to maintain balance or may cause pressure on the nerves and blood vessels of the legs. In maintaining either a constant sitting or standing posture, the tone of the muscles must be adjusted to a fixed position. The constant pull and stretch on the tendons and joints in maintaining a fixed position may set up unpleasant or even painful sensory stimuli. The height and width of the work bench also are important since constant stretching and reaching are fatiguing. Constant walking on hard floors causes a jarring effect on the joints. Concrete floors are the least resilient, whereas floors made of wood or, better still, those covered with linoleum, rubber tile, cork, or other composition materials are much less fatiguing.

An understanding of the physiological stresses imposed by various postures should guide industries in planning their operations and in building their equipment. Changes in posture are very desirable; constant standing is undesirable. The height of work benches should be adjusted so as not to require either constant stooping or constant extension of the arms without support; chairs should be adjusted to the size of the workers; and more attention should be paid to the character of the floor. The proper arrangement of work materials and adjustment of machines to fit the individual worker can alleviate much industrial fatigue.

**Effect of Work and Fatigue on Health and Disease.** One of the important questions in industrial hygiene concerns the effect of work and fatigue on suscepti-



bility to disease and on longevity. It is almost impossible to answer this question because of the many variable factors involved and the lack of adequate data. Animal experimentation is of limited value since it is impossible to reproduce the conditions of work and fatigue in animals comparable to that of humans, except possibly in regard to physical exercise. Statistical studies on man likewise are of little value. However, some idea of the prevailing data and opinions may be obtained from the following brief review.

**EFFECTS OF PHYSICAL EXERCISE ON THE SKELETAL MUSCLES AND HEART.** Laboratory experiments have shown that repeated contractions of skeletal muscles in performing heavy physical work usually lead to an increase in the size, strength and tone of these muscles. Even work which requires maximal contractions of skeletal muscles does not appear to damage the muscles. Exercise of certain types, if repeated regularly, may lead also to an increase in the size and strength of the heart. Exhaustive exercise does not appear to damage the heart. These laboratory experiments support the current opinion that stress produced by heavy physical work does not lead to any irreversible physiological changes in the skeletal muscles, the heart muscle or the blood vessels, provided these tissues are in a normal state. Most cardiologists agree that physical exertion is not a factor in acute coronary occlusion. Authorities differ regarding the relation of severe exertion to coronary insufficiency.

**EFFECT OF WORK AND FATIGUE ON SUSCEPTIBILITY TO INFECTIOUS DISEASES.** The effect of physical exercise on susceptibility to infectious diseases has been studied in animals. The evidence suggests that resistance to acute respiratory infections, such as pneumonia, is lowered when the animals are forced to run to exhaustion, especially if the infection is present before the fatiguing exercise. In man there is ample clinical evidence that physical overstrain has a deleterious effect on the course of active tuberculosis. Rich (1944) attributes this effect to the increase in respiratory movements, which may cause rupture of partly caseous blood vessel or necrotic lesions and mechanical spreading of bacilli or caseous material impregnated with tuberculo-protein. According to Rich "the harmful effects of over exertion are also evident in the case of arrested but not entirely healed tuberculosis." Kammer reported that there were fewer unfavorable reactions among men with inactive tuberculosis when they were engaged in light work than among those engaged in heavy work.

**EFFECT OF EXERCISE ON THE DIGESTIVE TRACT.** Some animal studies have been directed toward a study of the effects of physical exertion on the digestive tract. A recent experiment indicated that muscular fatigue brought about by exhaustive running on a treadmill, abetted the occurrence of gastric or duodenal ulcers produced by chronic histamine stimulation.

**EFFECTS OF EXERCISE AND WORK ON LONGEVITY.** Some studies have been made on the relation of strenuous athletics and physical work to length of life. Studies of deaths among college athletes who graduated some years previous showed that there was no marked difference in the mortality of this group as compared with that of a control group of students who were not outstanding athletes. Mortality and morbidity statistics in relation to occupation are influenced by so many factors that no definite conclusions can be drawn from them in relation to the effect of heavy work on mortality. At the present time there is no conclus-

evidence that fatigue due to exhaustive physical exercise and heavy muscular work in industry increases mortality.

EFFECTS OF NERVOUS TENSION ON HEALTH. It is universally accepted that long hours of work, nervous tension and worry about work are important factors in certain types of circulatory, gastro-intestinal, and other functional and psychosomatic disturbances.

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## THE PROMOTION AND REGULATION OF INDUSTRIAL MEDICINE AND HYGIENE

### GOVERNMENTAL AGENCIES

**United States Public Health Service.** The first official industrial hygiene agency in the United States Public Health Service was established in 1914 as the Office of Industrial Hygiene and Sanitation in the Scientific Research Division. Subsequently a Division of Industrial Hygiene was organized. At the present time (1955) industrial hygiene activities are being carried out by the Occupational Health Program of the Public Health Service, located in the Division of Special Health Services, under the Bureau of State Services.

"The Occupational Health Program of the Division consists of field and laboratory research studies of occupational disease; development of measures and standards for application by industry and by organizations engaged in the prevention and control of diseases and health hazards found in the work place; and the advancement of privately financed health maintenance services for workers. Other major activities include consultative services in the fields of occupational medicine, engineering, nursing, toxicology, biochemistry, and statistics and studies of the reporting of occupational diseases and sickness absenteeism. Special advisory assistance is made available to State and local agencies and other organizations on complex problems which arise in the administration of occupational health programs and services. Research activities are centered at the field headquarters in Cincinnati, Ohio, and a field station in Salt Lake City, Utah."\*

The staff of the Occupational Health Program today includes physicians, toxicologists, engineers, chemists, physicists, statisticians, nurses, and various types of laboratory personnel. This unit is primarily concerned with industrial hygiene research and its application; it provides information and assistance in this field to industrial, labor, medical and all other types of personnel concerned with the health of the worker. The Program has no law-enforcing powers and is not concerned with labor-management relations, wages, or any controversial economic problems of industry.

**State and Local Health Agencies.** Until the passage of the Social Security Act in 1935, only a few states had official agencies which were actively engaged in industrial hygiene work. Through the financial assistance of grants-in-aid allowed by the Social Security Law, and under the stimulus of the then Division of Industrial Hygiene of the Public Health Service, the state health departments began to develop

\* This quoted material is taken from Public Health Service Publication No. 165, *Industrial Hygiene*, 1955.

Industrial hygiene programs. In December 1955, 40 states,\* 13 cities, 6 counties, territories and the District of Columbia had active industrial hygiene programs. These programs are administered by the health departments in all states except New York, Massachusetts and Illinois where the industrial hygiene work is under the labor departments. The funds for these units are derived partly from the general health funds of the states and partly from federal grants-in-aid.

The state industrial hygiene agencies are engaged in various types of services. The most important activities are the field surveys of industries. These are performed as a part of routine investigations or upon request from industries. In these surveys the environmental and working conditions are examined. Where hazardous chemical substances exist in the working environment, air samples are collected and analyzed in the chemical laboratories which form an essential part of every industrial hygiene unit. If dangerous substances are found to exist in harmful concentrations, control measures are recommended.

The state agencies also advise industries regarding the incorporation of preventive measures in the design of new plants. Medical evaluation of working conditions is also made by studies of medical records and in some cases by examinations of the workers. The state agencies advise management and physicians concerning the toxicity of materials being used or produced in industry and regarding the diagnosis and treatment of occupational diseases. In addition to these services, the industrial hygiene divisions are actively concerned with atmospheric pollution control, the potential health dangers in the agricultural industry, and the protection of persons exposed to radioactive materials in industries, the control of noise, general ventilation and illumination of industrial plants, and all other industrial health problems.

Considerable work is done in assisting individual plants in organizing or improving health services for their employees. Some units have taken an active role in setting up cooperative medical services for small industries. These units also collect reports of cases of occupational illness and investigate the source of these. Each agency devotes considerable effort to educational activities by informing labor, industry, civic and professional groups on different phases of industrial health. In addition to direct industrial hygiene services, the agencies bring to industry more or less complete health programs by integrating their work with that of other divisions in the state government, unofficial health groups and professional organizations.

**Labor Departments.** The United States Department of Labor was created by Congress in 1913, to foster, promote, and develop the welfare of wage earners in the United States, to improve their working conditions, and to advance their opportunities for profitable employment. In carrying out these functions, the Labor Department has been concerned primarily with the economic and legal aspects of industrial work. The role of the Labor Department in industrial hygiene has been limited chiefly to the promotion of sanitation, to the prevention of accidents, to the regulation of hours of work, and to the control of types of work for women and children. The department has pursued this course chiefly by factory inspection, collection of statistics and support of labor legislation. The Bureau of Labor

\* States not having industrial hygiene programs in 1955 were: Arizona, Arkansas, Delaware, Nebraska, Nevada, North Dakota, South Carolina, Washington.



Statistics, the Bureau of Labor Standards and the Women's Bureau are the present divisions of the Labor Department which are concerned with these aspects of industrial hygiene. The industrial hygiene activities of the state departments of labor, with the exception of New York and Massachusetts, have followed the pattern of the federal department. The labor departments of New York and Massachusetts have separate divisions of industrial hygiene which are actively engaged in all phases of industrial hygiene and safety work.

**Location of Industrial Hygiene Divisions: Health or Labor Departments.** There has been considerable discussion as to whether industrial hygiene work should be located in health or labor departments. If the objectives of industrial hygiene as set forth in this book are accepted, then it is obvious that industrial hygiene is, indeed, public health in industry and, hence, should be the responsibility of the health departments. Only when labor departments engage personnel trained in medicine, public health, and industrial hygiene, as in New York and Massachusetts, are they able to conduct adequate programs in industrial hygiene. Even under these circumstances, the industrial hygiene programs are handicapped by the lack of the other branches of a health department which cooperate to make an all-inclusive health program for industrial workers. A very strong argument against placing industrial hygiene programs in the labor departments rests on the fact that these departments are primarily concerned with economic, legislative and labor-management problems. It is very desirable to have health activities divorced from such controversial and often political issues. Unquestionably, the health interests of the worker can be served best by health departments whose only function is the promotion of health of all persons in all places.

**The Bureau of Mines.** The United States Bureau of Mines was established in the Department of the Interior in 1910. One of its functions is to promote the safety and health of miners. This agency has been actively concerned with the effects of harmful substances encountered in mining and in allied industries and on the control of underground exposures to these materials. The bureau was granted law enforcement power in 1953 but until 1941 it did not have even the right of entry into mines.

**Other Governmental Agencies.** Several other governmental agencies are concerned with industrial hygiene problems of limited groups. The Children's Bureau formerly in the Labor Department but now located in the Department of Health Education and Welfare, deals with certain health problems in the employment of children, and with the effects of industrial work on pregnancy. The Department of Defense, Army, Navy, and Air Force maintain industrial hygiene personnel within the framework of their medical departments. These units are concerned with the health and working conditions of civilians who are employed by the Department of Defense. The Atomic Energy Commission is concerned with the protection of persons engaged in atomic energy work and supports research investigations on the effects of radiation on health.

## NONGOVERNMENTAL AGENCIES

Many agencies and organizations are actively concerned with the promotion of industrial hygiene, such as national professional associations and societies. A list

number of medical institutions, universities, private industries and insurance companies are engaged in research work or in teaching in the various fields of industrial health.

One of the best known of the private institutions is the Industrial Hygiene Foundation, started in 1938 by a group of private industries.\* "It is a nonprofit association of industries for advancing industrial health, improving working conditions and bettering human relations." The staff includes physicians, chemists, engineers, biochemists, and medical technicians. The activities of this organization fall into three categories:

"(1) To give direct professional assistance to member companies in the study of industrial health problems and their solution.

(2) To assist companies in the development of health programs as an essential part of industrial organization.

(3) To contribute to the technical advancement of industrial medicine and hygiene, through research surveys and allied activities." †

## INDUSTRIAL HEALTH PROGRAMS WITHIN INDUSTRY

**Changing Concepts of Industrial Medicine.** Originally medical services in industries were organized solely for the treatment of occupational injuries. Hence, surgeons were employed and the program was one of treatment only. With the growth of workmen's compensation laws, pre-employment physical examinations were added to the program. These were designed to prevent the employment of persons with pre-existing diseases, such as hernia, epilepsy or hypertension, which might lead to occupational injuries. The prevention of industrial accidents was assigned to safety departments, which were organized separately from the medical departments. When the compensation laws were extended to include occupational diseases, the treatment of these diseases was added to the responsibilities of the medical departments, and the pre-employment examinations were extended to detect persons with pre-existing diseases, such as silicosis. The prevention of occupational diseases was, in part, assigned to medical departments. In chemical and other industries where occupational diseases, rather than injuries, were the major problem, physicians, instead of surgeons, were employed. At first, the industries relied on outside agencies, such as governmental industrial hygiene divisions and insurance companies, for advice regarding the special engineering procedures necessary to prevent occupational diseases. In very recent years, the larger industries have developed industrial hygiene engineering divisions either as separate divisions or as part of the medical departments within their own companies.

With the advent of World War II, and with the accompanying labor shortage, became necessary for industries to employ injured veterans and persons with various types of disabilities and handicaps. This situation led to a considerable change

\* By 1955 this organization had almost 400 member companies.

† The quoted material is taken from "Industrial Hygiene Foundation Memo to Members" on Facilities, Services and Membership, 1951.



in the objectives of pre-employment examinations, and thus to a change in their name. Whereas in the earlier days the examinations served primarily to prevent the employment of certain persons, later they served to determine the ability of persons for work so that they could be placed in jobs suitable to their physical capacities. With this change in function, they became known as preplacement examinations.

In very recent years, the more progressive industries have come to realize that measures directed toward the prevention of nonoccupational diseases and toward the improvement of the health of the workers result in benefits to the company as well as to the workers. Analysis of sickness and accident records showed that occupational illness and injuries were relatively unimportant as a cause of sick-absenteeism but that absenteeism due to ordinary nonoccupational sickness and accidents, and the inefficiency of workers when suffering from non-disabling illnesses while at work, were major factors which interfered with production. Thus, programs designed to promote better health of the workers and to prevent disease are now being incorporated into industrial health services. Many industries have found that better labor-management relations follow the establishment of industrial health services when these services are designed for the benefit of the worker and not for compensation purposes. Insurance plans for the payment of medical and hospital services for nonoccupational diseases have been fostered by many industries.

Along with the growth of medicine in industry, interest in industrial health has been developing in the labor unions. In the past, this interest centered in prepayment medical care plans, although some labor union contracts carried clauses dealing with safety and sanitation within the plant. During World War II and the post-war period, the health and welfare provisions in union contracts have increased in scope, and clauses dealing with the health and medical services to be supplied by industry have been included in some instances. In recent years, some of the medical care services operated under union direction have become concerned with preventive medical work and rehabilitation as well as with medical diagnosis and treatment.

From this brief review, it is evident that the emphasis of health programs in industries is changing from surgical services to comprehensive preventive medical services. This trend reflects the growing interest in preventive medicine and the social changes in the world today.

**Current Industrial Health (Medical and Hygiene) Programs.** Modern health programs in industry can be divided into four phases: curative medicine; preventive medicine and health promotion; industrial hygiene engineering; and health research.

**CURATIVE MEDICINE.** The first duty of an industrial medical department is to operate a dispensary for the treatment of occupational injuries and illnesses. Usually the seriously injured are now sent to consultant surgeons. First aid and emergency treatments for nonoccupational illness are given. The immediate reporting and treatment of even minor conditions often can prevent more serious illness. In some large industries and in those in isolated areas diagnostic services for nonoccupational diseases are provided. The results of the diagnostic tests are given to the employees' private physicians upon request.

**PREVENTIVE MEDICINE AND HEALTH PROMOTION.** Medical examinations of employees form a major part of the preventive medical services in industry today. Preplacement physical examinations at the time of employment are designed to determine the physical ability and temperamental qualifications of employees in relation to the requirements of the job. In some industries, very thorough physical examinations, which include chest x-rays, blood and urine studies, electrocardiograms and tests of vision are made. Applicants are then classified as fit for any type of work, physically unfit for employment, or employable only in certain types of work. The jobs are often analyzed as to their physical requirements so that workers can be selected accordingly. Physical examinations are usually performed for the same reason when a worker is transferred to a new job. By means of such examinations, persons with physical or emotional handicaps can be placed in jobs within their limitations. Periodic physical examinations also are performed on all employees in some industries. In other industries, only those workers who are engaged in hazardous occupations are examined periodically, the frequency depending on the nature of the exposure. By such examinations, the early effects of harmful exposures can be detected and preventive measures can be immediately instituted. Physical examinations are given usually when employees return to work after an illness to determine if they have recovered sufficiently for work and if they present a hazard to their fellow workers. In some industries dental examinations of employees are included in the program.

There is no doubt that the physical examination programs in industry can be of great benefit in preventing many cases of serious illness. Whereas private physicians usually do not see patients until they become ill, the industrial physician, through these repeated examinations, often can detect cases of tuberculosis, venereal disease, diabetes, cardiovascular and other diseases in their early stages. By sending these patients at once to their private physician, serious illness may be prevented. Thus, medicine in industry is of great value in the early detection of nonoccupational diseases. In order to make the dispensary care and the physical examination programs of greatest value for the prevention of diseases, adequate records must be kept and analyzed regularly. A study of such records often directs attention to unrecognized hazardous conditions in the plant. Furthermore, such records indicate the workers who have repeated illnesses and may need medical or psychiatric care or who may need the assistance of a social agency.

Supervision of food handlers, vaccination of employees where certain diseases are endemic, nutritional programs, and health education of the employees are all part of preventive medical programs in progressive industries.

The industrial physicians and nurses work with established community agencies which are engaged in rehabilitation, public health, and welfare work.

**INDUSTRIAL HYGIENE ENGINEERING.** The activities of the industrial hygiene engineers are directed toward preventing hazardous exposures in the industry. When new plants are constructed, the industrial hygiene engineer designs the preventive measures so that they can be built into the original plant. In old operations, the industrial hygienist studies all processes to determine whether a harmful condition exists and designs protective equipment where necessary. The industrial hygienist and the plant physician must be acquainted with all of the toxic chemical



substances in the plant. Constant supervision of protective equipment is also a necessity.

In addition to the prevention of hazardous exposures, the industrial hygienist is engaged also in the prevention of atmospheric pollution with industrial wastes. The industrial hygiene program includes supervision of sanitation (food and water), general ventilation, lighting, etc. In plants where exposure to radioactive materials is a major problem, health physicists are employed to supervise the protection of workers exposed to dangerous radiation. The industrial hygienists are also concerned with the design of machinery and processes so that these will place a minimum of stress on the workers.

**INDUSTRIAL HEALTH RESEARCH.** Although most industrial health programs do not include research, industrial medicine offers opportunities for some types of research not available elsewhere. For example, the industrial physician, through the repeated medical examinations, has an opportunity to study the onset and development of chronic diseases over a period of years. Fundamental research problems connected with the occupational diseases can be studied most effectively by the physician who has an intimate knowledge of the exposure. These and many other problems could be the subject of research by industrial medical departments. Some industries maintain toxicological and medical research laboratories.

**Organization of Industrial Health Programs in Large and Small Plants.** The objectives of industrial health services for large and small industries are the same; the only difference lies in the methods of obtaining such services.

In very large industries, the medical departments are staffed by full-time physicians or surgeons, trained nurses, and laboratory technicians; the industrial hygiene staffs include mechanical engineers and chemists, and the safety divisions employ safety engineers.

The smaller industries cannot support complete health services, nor do they require full-time staffs. Often a full-time nurse working under the supervision of a part-time doctor can direct the industrial health work of a plant. In very small plants, only part-time nurses may be employed. Industrial hygiene engineering services can be obtained from state or local governmental agencies free. In some cases a number of small plants located in the same neighborhood have organized an industrial health service to serve all of the plants. Medical, nursing and industrial hygiene engineering services may be included in this arrangement. Small plant health and medical programs have been reviewed by Klem and others. Many insurance companies have developed excellent industrial hygiene departments, because they carry either industrial compensation insurance or life insurance policies for groups of industrial employees. In fact, the insurance companies have been among the pioneers in the field of industrial hygiene. They frequently employ engineers, chemists, physicians, nurses, and other personnel who advise industries in the prevention of occupational diseases and in the promotion of the health of their employees.

The relation of the industrial health services to all other branches of industry is important. The medical, industrial hygiene, and safety services should work closely together. All authorities agree that the health divisions should be directly responsible to top management—the president or vice president.

The number of doctors, nurses, and industrial hygienists required for different sized industries depends on the type of industry and the extent of the program. Similarly, the cost of health programs in industry varies with the size and type of the plant and the character and extent of the program. Special publications should be consulted for information on these phases of industrial medicine (Sappington, 1948; Am. College Surg., 1946; Nat'l Ass'n Manuf., 1941; Gafafer, 1943; periodic reports of the Industrial Hygiene Foundation). Information regarding the organization of industrial medical departments may be obtained from the Council on Industrial Health of the American Medical Association.

**Value of Industrial Health Programs in Industry.** It is difficult to measure the value of industrial, medical, and hygiene services in industry just as it is difficult to measure the value of any preventive medical program. However, practically all companies which provide good health services believe that the benefits both to the employee and the employer far outbalance the cost. The benefits to the employees are obvious: reduction of occupational diseases and accidents, reduction of non-occupational illness by early discovery of diseases and first-aid treatment, improved general health, and less lost time due to illness.

The benefits to industry are perhaps more difficult to evaluate. A good health program results in less absenteeism, less labor turnover, greater efficiency at work, better plant morale, better labor-management relations, and lower compensation costs. Various attempts have been made to estimate the financial value to industry of industrial health programs. One such estimate was made by the National Association of Manufacturers in 1941 on the basis of a survey of 2,064 industries. This survey indicated that a company with 500 employees could expect an annual net profit of \$5,611.00 to result from an industrial health program. This saving was based on a 47 per cent reduction in compensation costs for industrial accidents and diseases, plus a 28 per cent reduction in lost time due to nonindustrial illnesses and injuries, minus the cost of the health and safety program. Additional savings would result also from the accompanying reduction in labor turnover and insurance premiums. Similar calculations by Pharris (1950) indicated that a plant with 150 employees might save over \$7,000.00 per year as a result of an industrial health program.

In addition, as Stern (1946) pointed out: "The establishment of industrial health services involves more than the recognition that they yield long-run savings. It is an acknowledgment that the health of workers is as much of an asset to management as is the care of equipment, and that it is necessary to give as much attention to the effect of industrial materials and processes on the health of workers as to the problems of the pricing and the quality of the products. The limited distribution of industrial medical services bears evidence that the concept of conservation of human resources has not yet been fully incorporated into industrial management policy." The American College of Surgeons (1946) further stated: "In the past, industry has expended considerable effort and vast sums in maintaining its machinery and physical plants and found it to be 'good business.' The human machine in industry should receive no less attention for, after all, the human element is the most important factor in the structure, operation, and product of industrial organization."



## INDUSTRIAL HEALTH LEGISLATION

## GROWTH OF INDUSTRIAL HEALTH LEGISLATION

The growth of industrial hygiene in the United States can be followed, in part, by a brief review of the important legislation dealing with the conditions of work. In this country, the federal government has direct jurisdiction only over the working conditions for federal employees, although it can exert some indirect control over working conditions in private industry through taxation laws, the interstate commerce laws, and, more recently, through certain other types of legislation. Since the control and regulation of working conditions in the United States are primarily the responsibility of the state governments, the progress of industrial health legislation has varied greatly throughout the country, and even today marked differences exist in the laws of the individual states.

The first laws passed which regulated the conditions of work were those dealing with employment of children, hours of work for women, and prevention of accidents. The first child labor law was passed in Massachusetts in 1842. The progress of such legislation, however, was slow. As Stern (1946) pointed out, in the 50 years following this first law less than 12 states had made an effort to limit child work. Legislation concerned with the hours of employment for women began with the Massachusetts law of 1874. Some legal regulations designed to prevent accidents in factories and mines were enacted also in the late nineteenth century. By the end of that century, 14 states had some provisions for the inspection of factories and workshops, 22 states had similar provisions for mines, 21 states had some type of statute relating to the health of employees, and 13 states had laws for guarding certain types of machinery. By 1908, 17 states had regulations requiring devices for the removal of injurious dusts and gases. The laws passed up to this time were under the jurisdiction of the state labor departments, which were responsible for their enforcement.

Legislation relating to occupational diseases began in 1911 when California passed the first law which required the reporting of occupational diseases. Today, 28 states have laws which require that all or specified occupational diseases be reported to the health or labor departments. These laws have not been enforced.

The next major development in industrial health and safety legislation was the passage of the Workmen's Compensation Laws. The specific provisions of these laws will be reviewed in some detail later in this chapter. The first rather limited Workmen's Compensation Law was enacted by the federal government in 1908 for civilian employees engaged in certain hazardous occupations. It was not until 1916, however, that Congress passed a model compensation law for civilian employees of the United States. In the meanwhile, a number of individual states beginning with New Jersey and Wisconsin in 1911, passed such laws. By 1948 every state had passed a Workmen's Compensation Law. These laws are administered by special industrial accident or compensation commissions in some states and by the labor departments in other states.

One of the most significant advances in industrial health legislation occurred with the extension of the Workmen's Compensation Laws to include occupational diseases. The first such legislation was passed in California in 1918; Wisconsin and Connecticut followed in 1919. The passage of such laws has continued steadily

From that time, until by 1955, there were only two states which did not have some type of occupational disease compensation law covering at least part of the employed workers. The Workmen's Compensation Laws have been, by far, the most potent force in stimulating industries in the prevention and control of occupational accidents and diseases.

During the period when the states were enacting compensation legislation, several federal laws of importance were passed. The National Industrial Recovery Act of 1933 included regulations on hours of work, safety, and healthful working conditions for workers under the jurisdiction of the federal government. However, this act was declared unconstitutional. In 1936, the Walsh-Healey Public Contract Act gave the federal government direct jurisdiction over working conditions in the states for the first time. Under this law, the federal government was given authority regarding the safety of workers in industries which held government contracts above \$10,000.00 for the manufacture or furnishing of materials and equipment. According to Stern (1946), this law stipulates: " 'no part of such contract between the company and the government will be performed nor will any of the materials, supplies, articles or equipment to be manufactured or furnished under said contract be manufactured or fabricated in any plants, factories, buildings or surroundings under working conditions which are unsanitary, or hazardous or dangerous to the health and safety of employees.' " The federal Fair Labor Standards Act, which was passed in 1938, extended the principles of maximum hours and minimum wages to all workers in industries engaged in interstate commerce.

The most recent federal law which greatly affected the development of industrial hygiene was the Social Security Act of 1936. This law made it possible for the United States Public Health Service to allot grants-in-aid to each state for the establishment and maintenance of adequate public health services, including industrial hygiene programs. Unlike much of the preceding legislation which regulated either the conditions of employment or the payment of compensation, the industrial health programs initiated under the Social Security Law operate chiefly on a basis of education and service.

A compilation of the current industrial health legislation in state health and labor departments has been published recently by the U. S. Public Health Service (Brasko, 1954). Since these laws and regulations differ widely in the individual states, it is not possible to present them here.

#### WORKMEN'S COMPENSATION LAWS\*

**Objectives of Workmen's Compensation Acts.** Prior to the enactment of compensation laws, it was necessary for an injured worker or his dependents to sue the employer under the common law in order to collect indemnity for an industrial accident. In such a suit, the complaint was required to prove that the injuries were due to the negligence of the employer. The defense of the employer rested

\* This material was taken directly from the following bulletins issued by the United States Department of Labor and published by the United States Printing Office: Bulletin #123, Federal Labor Laws and Agencies, August, 1950 and Bulletin #161, State Workmen's Compensation Laws, September, 1954, and from lectures on Workmen's Compensation Laws given at the Johns Hopkins School of Hygiene and Public Health by Mr. B. E. Kuechle, Vice-President of Employers Mutual Liability Insurance Company of Wisconsin, and Mr. T. C. Waters, Chairman, Legal Committee of the Industrial Hygiene Foundation.



on three points: (1) the employee assumed the risk when he accepted employment; (2) the injuries were due to contributory negligence of the employee; or (3) the employee's fellow worker was negligent.

Under the common law procedure, the costs to the injured employee were high, and a large part of the indemnity, if collected, was spent for court and legal fees. Furthermore, there was a long delay before the injured man received his compensation. The disadvantages to the employer were the cost of defending the case and the unlimited monetary liability.

The Workmen's Compensation Laws have been developed to correct the disadvantages of the common law system. The objectives of the Workmen's Compensation Laws, as stated by Mr. Kuechle, are:

"To furnish certain, prompt and reasonable compensation to the injured employee consisting of medical treatment immediately after the injury and compensation to the injured employee or, in case of death, immediate compensation to his 'dependents.'

"To utilize for the injured employees all of the compensation money, much of which was lost to him under the common law system.

"To provide a tribunal where disputes between employer and employee in regard to compensation might be settled promptly, cheaply and summarily.

"To stimulate accident prevention.

"To provide 'rehabilitation' of workers who, because of their injuries, are no longer able to follow their former occupation."

Thus, under the Workmen's Compensation Laws the employee receives his compensation and other benefits promptly and without expense to himself. He does not have to prove negligence of the employer, but the amount of compensation is limited by law. The employer, in turn, assumes the responsibility for accidents, regardless of fault; but his liability is fixed by law.

**The Federal Compensation Law.** The federal government provides compensation for accidental injuries arising out of employment and occupational diseases under two laws: the Federal Employees' Compensation Act and the Longshoremen's and Harbor Workers' Compensation Act. The former provides compensation for civilian employees including civilian officers of the United States Government. The Longshoremen's Act covers maritime employment on navigable waters of the United States, except the master or members of the crew of a vessel. The principal employees covered are longshoremen and ship repairmen while on board a vessel. The law has been extended to other employments, including all private employment in the District of Columbia and employment outside the United States in the service of contractors with the United States at military, air or naval bases or on public works. Further details of the law and changes in the law can be obtained from periodic publications of the United States Department of Labor. The laws are administered by the Bureau of Employees' Compensation of the United States Department of Labor.

**State Compensation Laws.** Workmen's compensation legislation (covering accidental injuries) has been enacted by every state in the United States and by Alaska, Hawaii, and Puerto Rico. However, many workers are not covered by these compensation laws chiefly because: (1) the laws do not cover all occupations (agriculture, domestic service, casual employment, and in some instances, nonhazardous

employments usually are exempted unless voluntarily accepted by the employer); (2) many states have an elective system rather than a compulsory system; (3) in some states employers of fewer than a stipulated number of employees are exempt; (4) railroad workers and seamen engaged in interstate commerce are not included.

Legislation for the compensation of occupational diseases has been enacted as of December, 1955) in 46 states and in Alaska, the District of Columbia, Hawaii, and Puerto Rico.\* The occupational disease compensation laws are of two types: general coverage, and schedule coverage. The laws in 26 states and in Alaska, the District of Columbia, and Hawaii cover all occupational diseases (general coverage), while those in 20 states and in Puerto Rico cover only those diseases listed specifically in the laws (schedule coverage). The federal law is a general coverage law. The financial provisions in the case of occupational diseases are usually the same as those for accidental injuries except with respect to silicosis, asbestosis, or other dust diseases. In 26 states, benefits payable for silicosis or asbestosis are subject to certain limitations, while in 14 states no benefits are paid for partial disability in silicosis or asbestosis.

Provisions concerning death benefits, provisions for less serious injuries, and other details of the compensation laws vary in the different states.

In some states, medical consultants or medical boards are appointed to pass on medical problems in connection with occupational disease compensation. In some cases, their findings regarding the medical facts are conclusive; in others, they are only advisory in nature.

One of the most desirable features of the Workmen's Compensation Laws is the stimulus given for the prevention of accidents and occupational diseases. Insurance costs vary with the amount of benefits paid. In some laws, penalty payments on employers themselves, even though they are insured, are required where accidents occur because of violations of safety laws. Specific provisions for the prevention of accidents and occupational diseases are written into some compensation laws.

There are many other features of compensation laws, such as second injury benefits, waivers, rehabilitation provisions, etc., which cannot be reviewed here. The various state laws should be consulted for these and other provisions. These laws are summarized periodically in publications by the United States Labor Department.

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## Section Seven

# SANITARY CONTROL OF WATER SUPPLIES, SEWAGE AND REFUSE DISPOSAL

## 36

### WATER

EDWARD W. MOORE, M.A.

#### GENERAL CONSIDERATIONS

Water is a primary necessity of life; in its absence the higher animals will survive but a few hours or days. In addition, it contributes in a variety of ways to the enjoyment, safety and progress of human existence. The more advanced a human society is, the greater become its water needs and the more complex are the problems of public water supply and use. A statement of the uses of water in a modern community would include: *drinking and culinary uses; ablution and washing; heating and air-conditioning of buildings; watering of lawns, gardens, and parks; street sprinkling and cleaning; display in fountains; creation of hydraulic and steam power; quenching of fires; use as industrial process water; recreational uses, such as swimming and wading pools; and the removal of offensive and potentially dangerous household (sewage) and industrial wastes.* Of these uses, the ones shown in italics are of the most immediate sanitary concern, because water so employed may become a medium for the transmission of disease.

In a modern community, the water supply system, or water works, collects the water from its natural sources—stream, lake, underground aquifer or, rarely, direct rainfall—purifies it if necessary, conveys it to the community, and distributes it to the individual consumer. The average consumption of North American municipalities is 100 gallons per capita daily. The sewerage system, or sewage works, collects the spent water—about 70 per cent of that supplied—purifies it if necessary, and discharges it to the rivers, lakes or tidal waters of the region or, frequently, to the land. The inland bodies of water may therefore serve both as sources of water and as recipients of sewage, thereby creating particularly vexing problems of sanitation.

The works created for these purposes are among the greatest, most enduring, and most costly of the engineering accomplishments of man; portions of systems of great antiquity are still in evidence.\* For the most part, however, little of them can be seen, because many of the major structures are buried in the ground. As civilization became more urbanized, the number and extent of public water supply

\* The date of construction of the Appian aqueduct carrying water to Rome is placed at 312 B.C. Eighteen other aqueducts were constructed at various times until A.D. 226. The one commenced by Emperor Caius and completed by Claudius, according to Pliny, cost 350,000,000 sesterces, or about \$12,700,000.



systems increased. For example, in the United States before 1800 there were only 16 public water supplies, serving 2.8 per cent of the population. By the mid-twentieth century these had increased to more than 13,000 supplies serving about 60 per cent of the population. The balance of the population lives principally under rural conditions and has recourse to small private supplies, sanitary control of which is difficult because of their wide distribution and excessive variation in quality and quantity.

**Classification of Water.** Water collected from natural sources has come into contact with many substances, and by virtue of its erosive and solvent properties has taken some of these into suspension and solution. These substances include organic and inorganic components, gases, liquids, and solids and, in addition, many living organisms. Some of these organisms are normal aquatic organisms; others are harmless, adventitious micro-organisms; but some are pathogens discharged by persons who are suffering from, or are carriers of, a disease that may be transmitted by water. The water then becomes a medium for transmitting infection. It is seldom possible to detect infection directly in water. The likelihood of its existence may be inferred from the degree of contamination. *Contamination* is the introduction into water of human or animal wastes, which may transfer infection, or of other substances, as chemical poisons, which may also render it harmful. *Pollution* is a term used primarily to denote impairment of physical attractiveness. Pollution is the introduction into water of substances of such character and in such quantity that they render it objectionable in appearance, taste, or odor. They may or may not contribute to contamination.

For practical purposes, then, water is classified as clean, polluted, or contaminated. (1) *A clean water* is one which is at all times free from contamination and safe for human consumption, as determined by laboratory analyses, sanitary survey, and continued use. It is also one which is attractive in its appeal to the senses. (2) *A polluted water* is one which has suffered impairment of physical qualities through the addition of substances causing turbidity, color, odor, or taste. (3) *A contaminated water* is one which may carry infection by reason of the addition of human or animal wastes or which has been rendered unwholesome by poisonous chemical compounds.

According to source, waters are divided into three classes: rain water, surface water, and ground water. That which collects in streams, lakes, ponds, and reservoirs is called surface water, and the water which percolates through the soil and collects in underground places is called ground water.

The standards by which the quality of water is judged are constantly rising. There is no doubt that many waters now considered satisfactory will not be acceptable in the future. A water must have more than the negative property of being safe; it should have positive qualities: it should be crystal clear, sparkling and inviting, cool and refreshing, and above all, palatable.

**Properties of Water.** Water is a substance with many unique properties. It is a clear, transparent, tasteless and odorless fluid, colorless in small quantities, pale blue through a deep column. It freezes at  $0^{\circ}\text{C}$  and boils at  $100^{\circ}\text{C}$  under barometric pressure of 760 mm. It is practically incompressible; it has its greatest density at  $4^{\circ}\text{C}$ . The specific heat of water is high, meaning that it takes much heat to warm it and much cold to cool it.

Water rises to a greater height in a capillary tube than any other liquid. Owing to this property, it clings tightly in the soil and rises to a considerable height above the underground water table, thus making vast areas of the earth arable instead of dry desert.

The difference in the amount of water vapor held in the air at varying temperatures is large relative to most other liquids.

Water is the most widely distributed of all substances. The hardest crystals and the driest rocks contain appreciable quantities; in fact, crystals could not form were it not for the action of water.

Practically all substances dissolve to some extent in water; it is the most nearly universal solvent known. It dissolves gases; for example, oxygen and carbon dioxide. These are among the important constituents of all natural waters. Both are always present in the air, and all rain water contains them. Carbon dioxide is also taken up by the water as it percolates through ground covered with vegetation. The presence of this gas increases the solvent powers of the water, enabling it especially to dissolve limestone and other mineral and organic substances. The presence of oxygen is essential to normal aquatic life.

The mobility of liquid water and water vapor and the ease of conversion from one to the other permit rapid circulation and universal penetration of water. The circulation of water has a great influence on climate and is largely responsible for the wide distribution of vegetable and animal life on the earth.

**The Uses of Water in the Body.** Water enters and leaves the body in greater quantities than does any other substance. Much of it passes through the body unchanged; but it also enters the structural composition of the body, as well as that of all foods, and hence in the broader sense is entitled to rank as a food, although it does not of itself build tissue or produce energy. The uses of water in the body may be summarized as follows: it enters into the chemical composition of the tissues; it forms the chief ingredient of all body fluids, maintaining proper dilution of these fluids; it prevents friction by moistening such body surfaces as the mucous and serous membranes; in the blood and lymph it furnishes a medium for the transmission of food to, and removal of waste from, remote parts of the body; and it serves as a distributor and regulator of body heat through the physical processes of heat transfer and evaporation.

Water constitutes about 70 per cent of the entire body weight; to maintain this level a healthy man will require, on the average, 1,800 to 2,100 ml. of liquid water every 24 hours, in addition to about 600 ml. taken in as a component of solid foods,\* or a total of 2,400 to 2,700 ml. Of this water intake, 28 per cent is lost through the skin, 20 per cent through the lungs, 50 per cent through the kidneys, and 2 per cent in other secretions and in the feces. One of the more frequent metabolic faults is failure to take enough water into the system.

**The Amount of Water Used and Wasted.** From a sanitary standpoint our aim should be to encourage a generous use of water but to discourage waste. The conservation of pure water and the economic use of purified water are pressing problems that a growing and expanding country must meet and solve as a matter of self-interest if not of self-preservation. Many large cities have at times experienced difficulty in meeting their water requirements.

\* Fully five-sixths of the food in an ordinary diet consists of water.



It is possible to get along with a very small amount of water. From 3 to 10 pints a day, depending upon the climate, are needed for drinking, and about 5 pints for cookery. In present-day American communities the problem is often not under-consumption of water, but needless waste.

For general household purposes the rate of consumption of water in round numbers is 25 to 50 gallons per capita per day, the volume varying with the standard of living. Industrial communities use water in much larger quantities. The rates range from about 75 to 275 gallons per capita per day and are seldom much less than 100 gallons. They tend to be lower in cities where the services are metered and also in smaller cities. In the latter, industrial and public uses and waste of water are generally not so great in proportion to population. There is always a difference between the amount of water delivered to a distribution system and that which reaches consumers; this is termed "water unaccounted for" and includes not only leakage, but under-registration of meters and certain municipal uses. In a well-maintained and fully metered system this discrepancy seldom exceeds 15 per cent. Some industries use very large amounts of water; for example, a brewery consumes 470 gallons for every barrel of beer produced, an electric power plant 80 gallons for each kilowatt hour, a paper mill 40,000 gallons per ton of paper made. When such industries are present in a community, the consumption rate will be very high, even when domestic consumption remains comparable with that of other communities.

Table 36-1. Water consumption in large American cities  
(Arranged in order of number of services)

City	Gallons per Capita per Day
New York, N. Y. . . . .	130
Chicago, Ill. . . . .	286
Baltimore, Md. . . . .	107
Buffalo, N. Y. . . . .	222
Washington, D. C. . . . .	139 *
Boston, Mass., Metropolitan District . . . . .	96
San Francisco, Calif., S.V.W. Co. . . . .	75 *
New Orleans, La. . . . .	111
Seattle, Wash. . . . .	218
Rochester, N. Y. . . . .	120
Atlanta, Ga. . . . .	100
Memphis, Tenn. . . . .	80
Springfield, Mass. . . . .	107

Derived from data in "Inventory of Water and Sewage Facilities in the U. S.," U. S. Public Health Service.  
\* Am. Civil Eng. Handbook, 1930.

**Causes of Water Waste.** In most American cities, from 25 to 50 per cent of water provided can be said to be wasted. Much of this waste is avoidable, and in the face of steady diminution of water resources and rising costs of purification considerable effort and expenditure to avoid waste are justified.

There are three principal causes of water waste: (1) leakage from the mains and service pipes; (2) waste from defective house fittings, and (3) waste resulting from carelessness. The first cause includes all hidden defects in the system.

Table 36-2. Water consumption in foreign cities

City	Year	Consumption (U. S. Gallons) per Capita per Day
London .....	1927	43
Paris .....	1911	38
Berlin .....	1911	35
Vienna .....	1914	37
Rotterdam .....	1919	29
Zurich .....	1918	63
Moscow .....	1930	26
Geneva .....	1919	118
Tokyo .....	1931	48

which allow the water to escape unperceived into drains and sewers or into the subsoil. It is possible to locate and check a large part of this waste by means of leak detector or pitometer surveys. These instruments function by measuring, or making audible, abnormal flows in portions of the system isolated for observation, usually at night.

The amount of water wasted by a leaky or improperly closed house tap is larger than one might expect. A one-sixteenth-inch stream under 40 pounds pressure will discharge 630 gallons in a day. In cities having severe winters the water in many houses is allowed to run continuously from the cold water faucet in order to prevent freezing.\* The waste from this cause is enormous and may be eliminated by placing the pipes so as to avoid the danger of freezing.

**WATER METERS.** It has been the universal experience that much water is thoughtlessly wasted where the service is not metered. There is no valid objection to a metered service; the cost of the meters is soon covered by the saving in water. Furthermore, metering defers and decreases future expenditures for water works. All measures for combating water waste by consumer education are temporary unless the effort of the water authorities is continuous; metering makes the consumer permanently conscious of the undesirability of waste.

**Dual Water Supply.** The possibilities of dual supplies of water—one of them expensive and inferior in quality but satisfactory for general garden, street, and industrial purposes, and the other of high quality for personal use—have long engaged the attention of engineers and sanitarians. Ancient Rome had this kind of supply, and Paris and other European as well as some American cities have it at present. The advantages and disadvantages of the dual system are evident. Even when the community served is intelligent and careful, the hazards of dual systems are considerable, because of the ever-present possibility of chance interconnection. They are seldom resorted to except through stress of circumstances.

A number of cities have a separate water distribution system under high pressure for fire fighting. Ordinarily, this system derives its water from the same source as the general supply. Auxiliary water systems are often provided for industries. Some of the older ones are connected with the municipal water mains through

\* In cities where this practice prevails, more water is used in the severely cold months than the summer months.



what is termed an approved cross connection. This contains special check valves and auxiliary testing equipment. There are other means of connection as well. All such arrangements are inherently hazardous, and a number of outbreaks of water-borne disease have been traced to faulty check valves or failure to break connections in such dual systems. Cross connections are prohibited by the rules of many state departments of health. Between 1938 and 1945, nine outbreaks of water-borne disease, comprising a total of 41,540 cases, were caused by cross connections with unsafe water supplies (Eliassen and Cummings, 1948). One of the outstanding instances was that of Rochester, New York, where a cross connection between a polluted high-pressure fire and industrial supply and the city water system was accidentally opened. The result was 35,000 cases of gastroenteritis and 6 of typhoid fever. The polluted supply was abandoned at once.

### SOURCES OF WATER

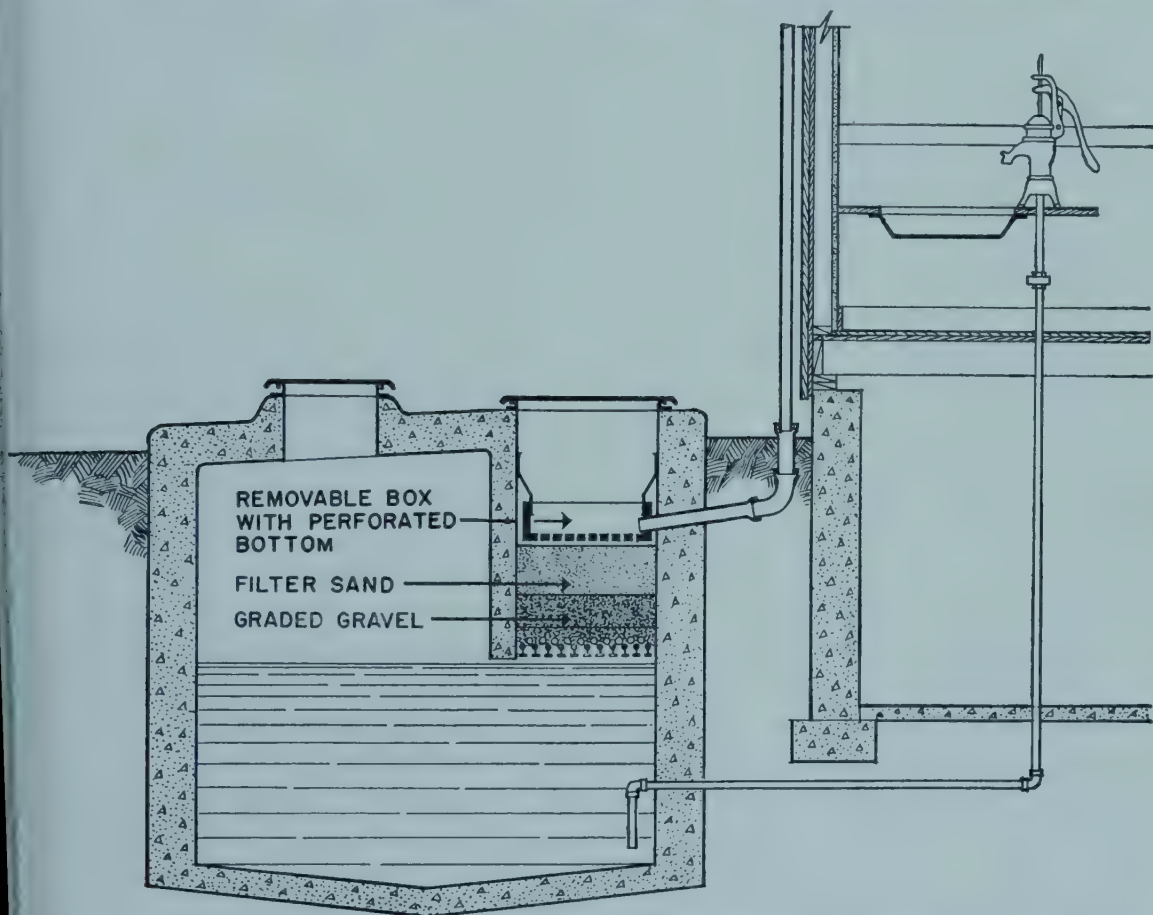
We may begin the circle by considering that all water comes to us from the aqueous vapor condensed in the form of rain or snow. Of this a certain amount returns to the atmosphere by evaporation; the rest collects upon the surface of the earth or soaks into the ground. Some of it flows off in the direction of surface slope to join the ponds, lakes, rivers, or seas, and some of it may penetrate the earth to varying depths. The sources of our water supply may therefore be classified as (1) rain or snow water, (2) surface water, including ponds, lakes, streams, and rivers, and (3) ground water, including springs and wells. This classification is an arbitrary one, used for convenience. There is no sharp distinction between rain, surface, and ground water. Rain water soon becomes surface water, and surface water may quickly pass into the ground; the ground water frequently reappears to feed streams and lakes and other surface supplies, especially at times of low surface runoff.

Rain water is nominally the purest, but is liable to irregularity of composition. In built-up sections it is difficult to collect it in such a way as to render it free from pollution and fit for drinking. Surface water from inhabited watersheds is, in its raw condition, never entirely safe for drinking purposes. Ground water obtained from the sandy subsoil of a catchment area that is free from sources of pollution is usually of a satisfactory character. Ground water obtained from the deep underlying strata may be so rich in mineral matter that it is unsatisfactory for most uses.

**Rain Water.** Rain water is really "distilled water"; that is, it is water that has been vaporized and then condensed. The process of distillation is one of the best known methods for purifying liquids of all kinds. All of the nonvolatile substances are left behind; theoretically, therefore, rain water should approach nearer to absolute purity than any other kind of natural water. However, it receives impurities from the moment it condenses, for droplets of mist are formed initially about a particle of dust in the air. The raindrop absorbs gases, near the seacoast it dissolves suspended salts, and as it drops through the air it collects some of the "dirt" floating in the lower portions of the atmosphere. Micro-organisms are also included. The impurities collected by the rain before it reaches the surface of the earth, while considerable in amount, are practically negligible from a sanitary

standpoint. After rain touches the earth's surface it becomes a surface water. If collected from a clean, impervious surface in the open country, it is the purest of natural waters. However, rain water for drinking purposes is all too frequently collected and stored in such a careless manner that it is subject to pollution.

The softness of rain water makes it useful in the laundry, and the absence of lime salts renders it desirable for cooking. On the whole, however, it is not considered as practicable as a good ground or surface water for a communal supply.



From Water Supplies and Sewage Systems for Farm Residences, Bd. Health Minn., March, 1925.

Fig. 36-1. Properly constructed cistern with sand filter, located outside the house to protect rain water.

The storage of rain water in cisterns and containers about the house was the principal factor in keeping yellow fever alive in endemic foci. The yellow fever mosquito (*Aedes aegypti*) breeds by preference in artificial containers holding clean water. It is the abolition of these breeding places that has protected cities and towns from the classical yellow fever epidemics.

Rain-water filters, constructed of coarse sand, may be employed to exclude impurities from the storage cistern. The filter medium should be regularly cleaned or replaced. It is desirable to provide means for wasting the first flow from collecting areas.

The gallons of water that may be collected as rain water may be estimated by multiplying the area of the receiving surface in square feet by one half \* of the

\* Six tenths is a more accurate factor, but as about 10 per cent is lost, one half gives more nearly the actual amount recovered.



rainfall in inches, measured by a rain gauge. Thus one inch of rain on a house roof 20 by 20 feet in area would be about 200 gallons. With a rainfall of 40 inches per annum, the yield would amount to 8,000 gallons. Losses by evaporation may be considerable, especially in warm weather.

**COLLECTION AND STORAGE.** Safe collection and storage of rain water for domestic purposes require careful attention to the following: (1) the care of the collecting surface; (2) the separation of the first flow, which contains most of the gross impurities; (3) the location and construction of the storage cistern.

Concrete storage cisterns are usually placed underground. Wooden ones are placed above ground; they must be kept full if they are to remain tight. Rain water attacks iron, lead, zinc, and other metals. Metals used in storing or conveying rain water should, therefore, be coated with a good asphaltum paint. Under no circumstances should lead cisterns or lead service pipes be employed for rain water that is to be used for drinking purposes. Surface drainage should be away from a cistern if pollution is to be avoided. Cisterns should be inspected and cleaned from time to time.

Overflow pipes from rain-water tanks should never be connected to drains carrying sewage, because of the danger of contamination through backing up of the drains.

**Surface Waters.** Surface waters include rivers, creeks, and smaller streams, large and small lakes, ponds, and impounding reservoirs. Their composition is highly variable and depends largely upon the character of the catchment basin. A water flowing over an uninhabited rocky soil or over sand and gravel is freer of organic impurities than one that has run over loam or has stood in swamps.

Surface waters are directly exposed to pollution by surface wash and water-carried wastes. They may be dangerous and are always open to suspicion. Because of the large yield of surface sources most cities depend upon surface waters taken from rivers, lakes, or impounding reservoirs. It is scarcely possible, in a populous country, to obtain a large quantity of surface water entirely free from pollution with human wastes. Sanitary engineers have, therefore, come to the conclusion that while surface waters used for drinking purposes should be protected from contamination as far as possible, they must be subjected at least to disinfection before use, no matter how good the protection.

**RIVERS.** Streams are the natural drainage channels of a region. Except along the seacoast and where sewage is used for the irrigation of crops, water-carried wastes must eventually find their way into them. If they are used as a source of water supply without treatment, they constitute, in a sense, a direct connection between the alimentary canals of the people living upstream and the mouths of those below. Most of our large rivers flow through more than one state; yet only recently have we provided legislation for dealing with stream pollution on a national basis. In some of the older countries of Europe, with more centralized power, laws to prevent the pollution of streams have long been enforced.

**STREAM POLLUTION VERSUS WATER PURIFICATION.** The succession of cities which use the river both as a sewer and as a source of water supply is particularly impressive on such rivers as the Merrimac, Hudson, Delaware, Ohio, Missouri, and Mississippi. The use of the waters of these rivers, raw and unpurified, has in the past caused much unnecessary sickness and has cost thousands of lives.

No stream draining an inhabited region can be considered safe without purification, even though the sewage flowing into the stream is completely treated. Storm overflows and street wash always add pollution which escapes treatment.

Normally it is cheaper to purify the water supplies taken from the rivers than it is to treat the sewage to the degree required for safety. But the cost of water purification increases with the degree of pollution, and a river can become polluted to such a point that no reasonable amount of treatment will produce a palatable and safe drinking water. Hence both water purification and sewage treatment are necessary, and one of the tasks of the sanitary engineer is to strike the proper economic balance between the two.

**COMPOSITION.** The composition of river water varies greatly from source to mouth and often from bank to bank. This complexity is due to the mixture of surface and ground water and to incoming wastes, each of which contributes a variety of impurities. Entering ground water as a rule contributes mineral matter and hardness by virtue of its longer contact with rock materials. Soil, swamps, sewage, and industrial wastes contribute organic matter; also some dissolved mineral substances; suspended particles of clay, soil, and waste; bacteria and other microscopic forms of life. In general, the mineral content of rivers is dependent upon the geological formations, the organic content upon the physiography of the area and the density of population.

Rivers are usually less polluted near their source because they generally originate in relatively uninhabited regions. Such pollution as is found is more apt to originate in swamps and from the erosion of clay banks.

The amounts of impurities increase as we descend the stream. Population centers tend to increase in size and number as the stream grows in its flow seaward and pollution may increase more rapidly than the volume of water and more rapidly than it can be eliminated by the forces of natural purification.

In broad, slow-moving streams, great inequalities in composition may be found through the cross section. These inequalities persist below the points at which tributaries enter or large volumes of waste are discharged.

Sudden and extensive changes in the character of river water occur at times of heavy rainfall. In a clean stream this dilutes the dissolved mineral constituents but it may increase the amount of organic substances, suspended solids, and bacteria. In a stream already heavily polluted a flood may cause dilution and relative decrease of all constituents.

General changes in composition, which come with increasing population and greater pollution, often occur over long periods of time. Such changes are of sanitary significance, for they indicate a retrogression in quality, a trend toward incipient nuisance, and an eventual sanitary menace.

**STREAM FLOW AND WATER-BORNE DISEASE.** Attempts have been made to correlate the flow of streams and the stages of a river with outbreaks of water-borne disease. Water-borne disease may be, and usually is, independent of the stage of the river. Such correlation as appears to exist at high stages is due to the fact that outbreaks are often connected with sudden freshets following a long dry spell. At such times there is much surface wash, the flow is rapid, infective material may be present and is then quickly carried for long distances, while nature's forces have not the time to destroy pathogenic bacteria in water. During the spring and



fall freshets, when the water is cold, this danger is greater, since the survival of pathogens is greater at lower temperatures.

**LAKES AND PONDS.** Fresh water lakes and ponds make admirable sources of water supply if kept free from pollution with human wastes. This is much more practicable than for rivers, on account of the limited area of the catchment basin directly draining into a small lake or pond. In large lakes the dilution of accidental contamination is enormous, and time, storage, sedimentation, and other purifying agencies have a good chance to exert their protecting influence. The sanitary problem in connection with large bodies of fresh water, such as our Great Lakes, is more concerned with mass pollution and is quite different from that of small lakes and ponds.

**THE GREAT LAKES.** The lake cities suffer most from the mingling of their own sewage with their own water supplies. This is avoided in part by building the intake structures far out into the lake and providing them with inlets that will permit drawing fresh, clear water that flows from the body of the lake to the intake. Lake currents are never constant. They are influenced in particular by wind; hence safety cannot always be secured. Almost every lake city has at one time or another suffered from outbreaks of water-borne disease. Improved sewage treatment and water purification have largely eliminated these outbreaks.

Pollution may travel a considerable distance in large lakes. At the mouth of the Detroit River, serious pollution was shown to extend more than 10 miles into the lake before sewage treatment was instituted, and at other places sewage pollution was shown to extend as far as 18 miles from the shore.\* The pollution from boats passing near the water intakes may be a serious menace.

**IMPOUNDING RESERVOIRS.** Impounding reservoirs are artificial ponds or lakes, usually made by throwing a dam across a narrow valley. Most impounding reservoirs are created along the course of a small stream. The principal use of impounding reservoirs is to convert an intermittent or fluctuating stream flow into a continuous water supply. This is done by holding the flood waters of the wet seasons in storage for use during the dry seasons. At the same time, the quality of the water is equalized by a mixture of the wet- and dry-weather flows. Time and relative quiescence permit the sedimentation of suspended particles, the bleaching, coagulation, and precipitation of colloidal coloring matter, and the destruction of objectionable aliens among the bacteria. Advantage is taken of the great sanitary safeguard of storage. Dangerous intestinal micro-organisms tend to die a natural death during the time when the water is stored in a large impounding reservoir. This time may be many months. Furthermore, there is primary protection in the fact that impounded supplies are usually located in sparsely settled or uninhabited districts.

The chief disadvantage of impounding reservoirs as storage basins is that they are liable to heavy growths of algae and other microscopic organisms responsible for objectionable tastes and odors. The stagnation of the lower layers of deep bodies of water also contributes to bad tastes and odors at certain seasons of the year.

**COLLECTION AND STORAGE.** The proper development of a catchment area for collecting and storing water calls for highly specialized engineering skills. The

\* Report of International Joint Commission of the United States and Canada.

amount of water that can be economically obtained is determined by such factors as the total amount of precipitation, its distribution throughout the year, and its occurrence as snow, the mean annual temperature and fluctuations from the mean temperature, the amount of water and swamp surface on the area, the nature of the cover and of the underlying geological structure, and the suitability of the area for dam sites.

In the New England region it is customary to plan for a storage of about half a year's supply in order to provide water at all seasons and to allow for fluctuations in run-off from year to year. In some parts of the West, however, storage may be required to meet not only seasonal deficiencies but also annual deficiencies, and so sufficient water has to be stored to serve over long periods of drought.

Many large impounding reservoirs have been and are being constructed to provide water for the larger cities. Among them may be mentioned the Quabbin Reservoir for the city of Boston, with a capacity of 415 billion gallons, the reservoir at Parker Dam on the Colorado River, serving Los Angeles, and the system of reservoirs on the tributaries of the Delaware River, which are being added to the New York water supply system.

**STAGNATION OF WATER; "OVERTURN."** Because water has a point of maximum density at  $4^{\circ}\text{C}$  and decreases in density on either side of this point, reservoirs, lakes, and ponds over 20 to 40 feet deep are subject to vertical stagnation. In the summer the warmer and lighter water remains at the surface. This upper layer is stirred to a certain depth by wind action and vertical currents caused by diurnal temperature fluctuations. The lower layer remains cool and quiet. There is a zone between the two layers, called the thermocline, where the temperature changes rapidly with depth.

As the air temperature falls with the approach of winter, the surface water cools down and approaches that of the bottom water. Density differences become small, and wind action and vertical currents mix the water from top to bottom. This is called the "fall overturn" and it continues for a few weeks, until the temperature of the surface water falls below  $4^{\circ}\text{C}$ . A period of winter stagnation then sets in, because the top water is lighter than that at the bottom. Preservation of quiescence may be aided at this time by an ice cover which protects the lake from wind action. As spring comes, the surface water again warms up until no density difference exists, and the "spring overturn" is set in motion.

These stratification phenomena have a great influence on the quality of the water. Organic matter accumulated in the bottom water decomposes, and may even deplete the oxygen entirely and produce putrefaction odors. Water drawn from these bottom layers may have an unsatisfactory taste and may contain substances such as iron and manganese in undesirable quantities. The fall and spring overturns bring to the surface a fresh supply of carbon dioxide, nitrogen compounds, and other substances favoring algal growths. The overturns are followed by pulses of algal growths, which create additional taste and odor problems. Departures from these occurrences are observed in the tropics and the Arctic.

**Ground Water.** Water that is taken from the ground by means of wells or that flows naturally from springs is often of better quality than surface water in the same area. The surface water is greatly improved as it percolates through the sandy soil. This is nature's process of filtration; the organic matter is oxidized.



the bacteria are largely strained out. The soil can take care of a large amount of pollution and will often yield ground water free of undesirable substances and bacteria. However, this is true only if the soil or rock is fine-grained and does not have cracks, crevices and bedding planes that permit free passage of polluted water. In passing through soil that is rich in decomposing organic matter, the water takes up a rather large amount of carbon dioxide. The water, thus acidulated, has a greater solvent action for lime and other mineral constituents, so that ground water is likely to be harder than surface water and to contain a larger amount of dissolved mineral matter. In deeper waters the solvent action is favored by longer contact with geological formations.

The water that soaks into the soil is finally supported upon an impervious stratum. As a rule, such water does not exist in the ground as a river or lake, but rather occupies the spaces between the sandy particles, except in limestone formations. Sandy, gravelly, or sandstone formations are good aquifers.

It is only in the crevices of limestone regions that ground water exists as flowing rivers or in large bodies. The sanitary hazard of water from limestone crevices or from shale and slate is always great.

Ground water finally reaches an impervious stratum. It then ceases to pass vertically downward and passes more horizontally through the porous stratum in which it is found. The surface of the ground water is known as the *ground-water table*. It is tapped when wells are sunk, and forms springs, lakes, and marshes where it crops out on the surface. It also contributes to the flow of streams during dry weather.

The surface of the ground-water table conforms, in general, to the surface of the land, but may depart from it. The ground-water table rises and falls to a certain extent with the rainfall. The rate of flow is of the order of miles per month whereas that of streams is miles per day.

**AMOUNT.** The amount of water that may be obtained from the ground can be determined only by means of actual pumping tests carried on for a sufficient length of time to bring about an approximate state of equilibrium between the supply and the draft as determined by the level of the ground water. Pumping tests of short duration are likely to be deceptive, as they may give copious quantities of water during the period of pumping; but this water may not be replaced quickly. For example, ground water may exist as a reservoir with little movement, corresponding to a surface pond with a small watershed. When the water is taken out, it may not be replaced for a long time. Ground water supplies are more generally available for, and better adapted to, the needs of small places than of large cities. In the United States there are more than twice as many communities that are supplied with ground water than with surface water. However, the total quantity of ground water delivered is far less.

In Europe ground water supplies have been provided for many large cities; corresponding large developments in America are rare, but industrial ground water supplies may be quite large. In many regions the yield has been depleted in the course of years, or population growth has raised the demand above the amount that can be safely provided.

Most ground water supplies are obtained from (1) sand and gravel deposits, (2) sandstone, (3) limestone formations. Some water may be drawn from the

cracks and crevices of granite and similar impervious rocks especially if they have an overburden of sand or gravel.

**GROUND WATER FROM SAND AND GRAVEL DEPOSITS.** Water flows through sand with some difficulty because of the frictional resistance to flow. A well draws water only from a limited portion of the surrounding area. This area of draft depends upon the depth and coarseness of the sand. Therefore, the way to secure a large quantity of water from such formations is by the use of a series of wells spaced so as not to interfere with one another or by the construction of a horizontal collection gallery, or gravel-filled area surrounding the well.

The amount of water that can be secured from a given area depends upon the rainfall, upon the evaporation from the surface of the ground, either directly or by the transpiration of vegetation, and upon the amount of storage in the pores of the soil. Ground water obtained from sand and gravel deposits is usually clear and free from unwholesome impurities.

Filter galleries near river banks that draw water from the stream through the ground are apt to furnish a diminishing supply, because the pores of the filtering material become filled with the sediment of the river water.

**GROUND WATER FROM SANDSTONE.** The method of driving wells in sandstone differs from that of driving wells in sand or gravel, but the collection, storage, and flow of water are precisely the same.

Aside from cementing material that binds what otherwise would be loose sand into a solid rock, sandstone acts substantially as so much sand would.

Water drawn from sandstone is well filtered unless the rock has been fractured by explosives. The Marshall and Potsdam sandstones underlying parts of Michigan, Illinois, Wisconsin, and Minnesota are used extensively for supplying towns and small cities.

**GROUND WATER FROM LIMESTONE FORMATIONS.** In limestone formations the water travels through fissures or passages. When these are large they are called caverns or caves, which are natural seams or cracks enlarged by the gradual solution and removal of the limestone by the passing water. Limestone and dolomite are the only common rocks that are soluble in this way and, for water supply purposes, these formations must be distinguished from all others.

The crevices may be, and often are, continuous for many miles. The direction and flow of the water may bear no relation whatever to the surface drainage. Pollution at one point may therefore endanger those using the water at a far-distant place.

A limestone formation has little ability to hold the abundant winter flows and to maintain a supply through droughts. The difference between limestone and sand in this respect is striking. While much water may be available, the amount is subject to great fluctuations, and the supply may fall short when most needed. From a sanitary standpoint, the fact is significant that water flowing through sand is filtered and purified, whereas no such action takes place in limestone fissures.

That contamination at one point may soon reappear at a far-distant point may be demonstrated by the use of fluorescent dyes, or by the use of massive cultures of some harmless micro-organism, such as yeast or *Serratia marcescens*.

Water-borne disease has been caused frequently by the use of ground water from limestone formations. A typical example is the Lausen epidemic (see Chap-



ter 3). *All water supplies from limestone formations must be regarded with suspicion unless properly safeguarded by appropriate treatment.*

**WELLS.** A well is a hole sunk into the earth to reach a supply of water and provided with some means for lifting the water to the surface. Wells may be either shallow or deep, and dug, drilled, or driven. The type depends largely upon the nature of the material through which the well is to be sunk. Shallow wells are usually dug and lined with stone or brickwork. Their diameter is usually five or six feet, but they may be much larger. They are rarely over 30 feet deep. Driven wells are made by driving wrought-iron pipes into sandy or gravelly soil. The pipe is fitted with a perforated strainer pointed at the end and covered with screening so as to allow entrance of the water and to exclude the sand and gravel. Deep wells are usually drilled. They consist of iron pipes or tubes, six to eight inches in diameter, and may extend many hundred feet into the earth. If the water is drawn from a depth of 100 feet or more, it is usually called a deep well. If the well passes through an impervious stratum into a pervious one beneath, it is spoken of as an artesian well.\* Water is usually drawn from wells by means of pumps or compressed air.

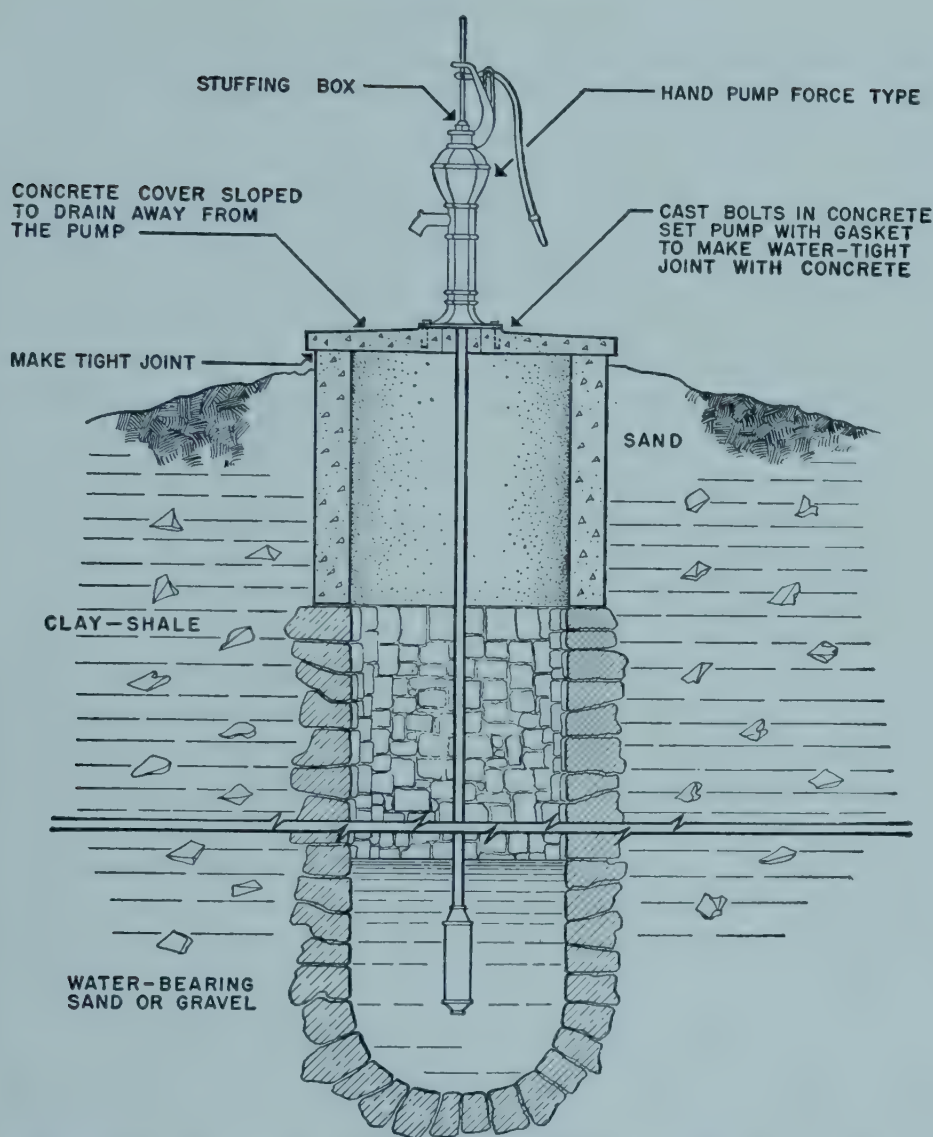
Except in limestone, wells are usually polluted from the surface. The filtering power of sandy soil or sandstone is usually sufficient to protect the water drawn from a well, unless a cesspool, broken sewer, or other gross source of pollution is close by. If channels, fissures, or crevices exist in sandstone or limestone, impurities may reach the well without undergoing filtration.

In locating a well, therefore, much depends upon the surface configuration of the ground, the character of the soil, and the proximity of possible sources of pollution. The casing of a dug well should be sound and tight, preferably of concrete of good quality. This impervious casing should extend 6 to 10 feet into the well. After it is laid, the outer space between the casing and the earth should be filled in with well-tamped clay soil or concrete. The casing should be extended 12 to 18 inches above the surface of the ground. The cover of the well should rest upon the top of the casing, so that no space is left for seepage water or vermin to enter. The cover is best made of reinforced concrete. It should slope away from the pump base and extend beyond the edges of the casing. Wooden covers are not satisfactory. The pump should be firmly fastened to the cover and surrounded with a flashing of tin to prevent water from washing back into the well.

The widely prevalent idea that some form of ventilation must be provided for a well is entirely erroneous. Well water keeps better in the dark and protected from the outer air and dust.

The tops of driven wells should be as carefully protected as those of dug wells, since otherwise polluted surface water may work down the sides of the pipe. Care should be taken that the pipes of a driven well near the surface of the ground do not rust and become leaky. Such wells should be provided with a heavy top, to which the pump frame should be tightly bolted in order to prevent loosening of the joints in the pipe by the vibration of pumping. The space between the base and the well casing of driven wells should be filled with grouting and overlaid with cement near the top. The ground about all wells should slope away and be kept clean, and

\* The word "artesian" is derived from Artois, an ancient province in France which was supplied with flowing wells. Artesian water may or may not rise to the surface of the ground.



From Water Supplies and Sewage Systems for Farm Residences, Bd. Health Minn., August 1921.

Fig. 36-2. Diagram showing how a dug well can be protected against pollution.

where possible, should be turfed. The waste water should be carried by pipes to a considerable distance from the well (Minnesota State Board of Health, 1921, 1923; New York State Department of Health, 1940).

Deep well waters in sand or sandstone furnish the safest and often one of the most satisfactory sources of supply. Such waters are usually clear and of high sanitary quality, but they sometimes contain a large amount of mineral matter, which renders them unfit for domestic purposes. They may contain iron or manganese, which soon oxidizes upon contact with the air and is thrown out as an insoluble compound, rendering the water yellowish or brownish. Deep well waters may contain an excess of lime and magnesium salts, common salt, hydrogen sulfide, carbon dioxide, etc.

*Location of Wells.* It is evident that in densely inhabited cities, with miles of sewers, some of them doubtless broken or leaky, the soil may be sewage-polluted and capable of contaminating shallow wells. Shallow wells, on general principles,



have been gradually eliminated from all large cities. The wisdom of this policy was shown by studies on typhoid fever in the District of Columbia, in which many of the shallow wells within the city limits were shown, by chemical and bacteriological analyses, to be polluted.

*Disinfection of Wells.* Temporary pollution of wells can be overcome by the addition to the water in the well of bleaching powder or calcium hypochlorite to provide a substantial chlorine residual. There is no remedy for continued pollution; the well must be abandoned, the source of pollution must be removed, or the water must be purified, boiled before use or otherwise disinfected. It is inadvisable for untrained persons to attempt chemical disinfection of the water.

**SPRINGS.** A spring is a stream of water flowing naturally from the ground. Spring water does not differ in any way from the ground water obtained from shallow wells. Spring water is subject to pollution from the same sources as well water and should not be regarded as safer than other ground waters. Spring waters differ greatly in character, especially as to their temperatures and the inorganic constituents which they contain. Springs may be perennial, the flow being constant, or they may be intermittent.

Springs may be contaminated from various sources and in much the same way as wells. The overlying porous layer of soil may be too thin to remove the contamination of surface washings from privies, stables, hog pens, and other places. Springs may be directly contaminated from surface washings; that is, the material may be washed down and into the spring by heavy rains, and unless the spring has a heavy flow, the material may remain in it for some time. The greatest hazards are found in spring water from limestone formations. A limestone spring that becomes muddy soon after a rain should be regarded as particularly suspicious.

## POLLUTION AND CONTAMINATION

**Sources and Nature.** Pollution refers to the entrance into water of substances, of any nature whatsoever, which impair its physical qualities. Vegetable matter from swamps and certain manufacturing wastes come in this category and have little influence upon health. Sewage may cause not only *pollution* but also *contamination* and is a direct menace to health. Contamination is a specific kind of pollution. These terms as used in connection with water are defined on page 1134.

Direct evidence of infection in water has rarely been demonstrated except in the case of cholera. Typhoid bacilli have occasionally been isolated from drinking water, but the technics are too laborious for general use. The evidence of water-borne infection is practically always epidemiological and is gathered after cases of disease have occurred. Contamination, however, can easily be established on the basis of field or laboratory findings, which show that wastes from man or animal have defiled the water. *Contamination is an index of potential infection.*

**Danger of Contamination.** The greatest hazard to man is found in a water contaminated with the alvine discharges from the human body. There is comparatively little danger from water containing the wastes of other animal life, for the reason that few of the infections of the lower animals are thus transmissible to man. There is practically no danger from water polluted with organic matter of plant origin.

**Prevention of Contamination.** The prevention of the contamination of surface waters is an important sanitary problem; the extent to which prevention is possible is determined largely by economic considerations. The most dangerous contamination is that which is recent in point of time, that is, that which is quickly transferred in a fresh and virulent form. It has become nearly impossible to maintain large streams and lakes entirely free from contamination. Substantial protection may be accomplished by installing sewage disposal works for all upstream towns and settlements and abolishing all overhanging privies upon the river and its tributaries. This requirement needs to be supplemented by continuous sanitary inspection. However, when a stream has a considerable population along its course, none of these measures affords complete protection. They help, but purification of the water must furnish the final safeguard. It is comparatively easier to guard small lakes, ponds, and impounding reservoirs than large streams and lakes.

**Legal Control of Stream Pollution.** The development and enforcement of laws for the prevention of stream pollution have lagged behind the scientific and technological means available for prevention. For many years enforcement was left up to the injured party, who had to resort to a damage suit under the common law doctrine that riparian owners were entitled to have the streams flowing past their property "undiminished and unimpaired, subject to a reasonable use" by the owners upstream. Many court battles were fought over what constituted "reasonable use," but the courts in general decided that pollution was not "reasonable." England was the first to adopt a comprehensive plan, backed by legislation, for country-wide abatement of pollution. This began with the Rivers Pollution Commission of 1855.

In the United States, until 1948, the regulation of pollution was left entirely to the separate states, with the Federal Government having jurisdiction only over navigable waters. All states have passed laws dealing with the subject; these vary greatly in effectiveness and enforceability. No two of them are alike but, in general, the control is vested in the state health department or in a separate water pollution control board. In some cases control is divided between two agencies. The penalties for violations vary from nominal to severe, and the powers of the agencies to make rules and regulations having the force of law may be extensive or negligible. The trend is to increase the authority of these agencies. Individual state laws do not deal with pollution which crosses state lines; such cases, where they have been dealt with at all, have been handled by interstate compacts and agreements.

In 1948 Congress passed a Federal Water Pollution Control Act. This provides that The Surgeon General of the U. S. Public Health Service shall have general supervision of stream pollution control activities. Initial enforcement of pollution abatement is left to the states, but The Surgeon General has power to enforce abatement if the states fail. The Public Health Service is empowered to establish a water pollution control advisory board and to assist states or interstate agencies with loans for construction of treatment works and funds for investigation and research. Pollution abatement activities under this new law are now in progress.

**Pollution of International Boundary Waters.** Under terms of Article IX of a treaty of January 11, 1909, between the United States and Great Britain, the questions of extension of pollution of boundary waters and remedies were referred to



the International Joint Commission under date of August 1, 1912. A sanitary survey was made of the Great Lakes District, particular emphasis being laid on sewage pollution from cities and towns, sewage from vessels, sawmill and other industrial and household wastes, and existing methods for their control. In general, the conclusions embodied in their report, 1919, are that it is "feasible and practicable without imposing an unreasonable burden on the offending communities to prevent or remedy pollution, both in the case of boundary waters and waters crossing the boundary. In case of city sewage, this can best be accomplished by installing collection and treatment works having special reference to the removal of bacteria and matters in suspension." The conclusion is made that vessels should treat their sewage before discharge, as for instance with live steam; also that water ballast discharge should be regulated with due regard for drinking water intakes for any neighboring community; further, that restriction should be placed on disposals of garbage and carcasses in boundary waters. The International Joint Commission has continued to regulate the pollution of boundary waters.

**The Care of Catchment Areas.** "Catchment area," "watershed," "drainage area," and "catchment basin" are terms used to include the area that contributes, by drainage to a particular stream, lake, or reservoir, the water that falls upon it. The ideal catchment area is free from human habitation and is covered with forests. The catchment areas supplying impounding reservoirs and the natural ponds and lakes used as reservoirs are limited in area when compared, for example, with the catchment areas of the great rivers, from which many public water supplies are drawn. It is, therefore, possible to inspect and control the former more readily than the latter.

It is often impossible to remove population from a catchment area. If the population is limited, proper precautions will ensure good water from the catchment area; but as population grows, the effectiveness of such precautions decreases. For example, population growth on the catchment area of the Sudbury Reservoir of the Boston water supply eventually forced the abandonment of this reservoir as a part of the regular supply. Similar changes have been forced on other cities, and treatment of waters once used without any purification has had to be instituted. The use of the automobile has greatly increased the hazard upon all such watersheds, for it is not possible to control effectively the habits of an itinerant population.

The prolonged storage of the water in large protected reservoirs is a sanitary safeguard and makes the Boston and New York supplies safer than they otherwise would be. The greatest danger lies in the fact that contaminated water may sometimes pass through a reservoir by short circuit, because of surface currents or unusual draft, and so reach the consumer before it has enjoyed the full benefits of purification by storage. Also the length of storage may be greatly decreased in times of drought. All such waters are now chlorinated.

The proper sanitary care of a catchment area requires, first of all, sufficient laws granting suitable authority, especially concerning the disposal of human wastes.

Care must also be exercised to keep out manufacturing wastes and the surface washings that may carry contamination from human sources or undesirable pollution. This object may be accomplished in various ways. The city should own the shores of the reservoir and also much of the land along the important streams. Old

sources of pollution must be removed and new sources prevented. Where the danger from human contamination is especially great, as around the impounding reservoir itself or at nearby suburban settlements, engineering projects, sometimes of considerable magnitude, are necessary to carry away the sewage and the surface drainage. A strict patrol of the catchment area and supervision of picnic and camping grounds and camps of construction gangs must be exercised.

In the investigation of a stream and its watershed, the chief points requiring attention are the relative proportions of polluting matter and the flow of the stream when at its minimum, the general character of the stream, the rate of flow, and the distance between the source of pollution and the water intake.

Water boards should plant their catchment areas with trees. Trees add to the retention of water and reduce erosion.

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## SANITARY ANALYSIS OF WATER

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Judgment as to the sanitary quality of an actual or a potential water supply is based on information obtained from two sources: field surveys of the water source and laboratory examinations of collected samples. Field or sanitary surveys determine the presence or absence of possible sources of pollution. Laboratory examinations indicate whether or not the collected samples of water contain substances that are indicative of pollution or that are themselves harmful or undesirable. The fact that a water supply has been used for many years without causing recognized cases of disease can be relied on as evidence of present and future fitness only if conditions surrounding the supply have remained unchanged. This is seldom true, and the adoption of a *laissez faire* policy should be guarded against. Repeated field surveys and routine laboratory analyses of collected samples are the only real safeguard.

**The Field Survey.** The field survey is of surpassing importance in judging the fitness of a water supply. It calls for a consideration of a great many items and should be entrusted only to persons who have by training and experience acquired a broad knowledge of those matters which are pertinent to the sanitation of water sources, to their physical development, and to the purification of water. The survey should deal with the following features, a complete discussion of which is given in the Manual of Recommended Water Sanitation Practice (U. S. Public Health Service, 1946a):

## A. GROUND WATER SUPPLIES

1. Character of local geology; size and topography of catchment area; slope of ground surface.

2. Nature of soil and underlying porous strata, whether clay, sand, gravel, rock (especially porous limestone); coarseness of sand or gravel; thickness of water-bearing stratum; depth to water table; location and log of wells in vicinity in use or abandoned.

3. Slope of water table, preferably as determined from observational wells or as indicated presumptively but not certainly, by slope of ground surface.

4. Extent of drainage area likely to contribute water to the supply, population on the drainage area.

5. Nature, distance, and direction of local sources of pollution.

6. Possibility of surface-drainage water entering the supply, and of wells becoming flooded; methods of protection.

7. Methods used for protecting the supply against pollution, by means of sewage treatment, waste disposal, and the like.
8. Well construction: material, diameter, depth of casing; depth to strainers or perforations; length of strainers or perforations.
9. Protection of collecting well at top and on sides; protection other than check valve, or gate valve, against backflow of drain; protection of collector lines, etc.
10. Pumphouse construction (floors, drains, etc.); capacity of pumps; draw-down when pumps are in operation.
11. Availability of an impure supply, usable in place of normal supply, hence involving danger to the public health.
12. Disinfection; equipment; supervision; laboratory control.

*Examples of Sanitary Defects in Ground Water Supplies:*

1. Caves, sink holes, or abandoned borings, used for surface drainage, or sewage disposal, in vicinity of the source; fissures or open faults in strata overlying water-bearing formations.
2. Casing of tubular wells leaky, or not extended to sufficient depth, or not extended above ground or floor of pump room, or not closed at top; or casing improperly used as a suction pipe.
3. Collecting well, or reservoir, subject to contamination by backflow of polluted water through improper drain or by entry of surface drainage. Lack of covers, improperly designed manholes, vent openings, etc., which may permit contamination.
4. Source of supply or structures subject to flooding.
5. Use of tile pipes, or other conduits, that are not tight where the ground water may be contaminated.
6. Leak in systems under vacuum.
7. Air-lift line, or lines, cross-connected to a sewer or secondary water supply.
8. Wells located near sewers; pit privies; cesspools; septic tanks; subsurface tile systems; drains; barnyards; pits below ground surface; or other sources of contamination.
9. Wellheads, well casings, pumps, pumping machinery, exposed suction pipes, or valve boxes connected with suction pipes, located in pits extending below the ground surface.
10. Manufacturing and industrial plant wastes discharged on watersheds, or to underground strata causing contamination of ground-water supplies.

**SURFACE WATER SUPPLIES, UNFILTERED**

1. Nature of surface geology; character of soils and rocks.
2. Character of vegetation; forests; cultivated and irrigated land, including fertility, effect of irrigation water, etc.
3. Population and sewered population per square mile of catchment area.
4. Methods of sewage disposal, whether by diversion from watershed or by treatment.
5. Character and efficiency of sewage-treatment works on watershed.
6. Proximity of sources of fecal pollution to intake of water supply.



7. Proximity, sources and character of industrial wastes, oilfield brines, acid mine waters, etc.

8. Adequacy of supply as to quantity.

9. For lake or reservoir supplies: wind-direction and velocity data; drift of pollution; sunshine data (algae).

10. Character and quality of raw water: coliform organisms (most probable number); algae; turbidity; color; objectionable mineral constituents.

11. Nominal period of detention in reservoir, or storage basin.

12. Probable minimum time required for water to flow from sources of pollution to reservoir, and through reservoir to intake.

13. Shape of reservoir, with reference to possible currents of water, induced by wind or reservoir discharge, from inlet to water-supply intake.

14. Measures taken to prevent fishing; boating; landing of airplanes; swimming; wading; ice cutting; permitting animals on marginal shore areas, and in or upon the water, etc.

15. Efficiency and constancy of policing.

16. Disinfection of water: kind and adequacy of equipment; duplication of parts; effectiveness of treatment; adequacy of supervision and laboratory control; contact period after disinfection; whether residual-free chlorine or chloramines used in chlorinated water; residuals carried.

17. Pumping facilities: pumphouse; pump capacity and standby units; storage facilities.

#### *Examples of Sanitary Defects:*

1. Absence, or inadequacy, of chlorination, or lack of proper control of chlorination; insufficient contact period when chloramines only are present in treated water.

2. No restrictions on recreational use of streams and reservoirs, together with their marginal lands, in the local catchment area.

3. Existence of sources of pollution, such as population on watershed, lumbering, hunting, grazing, and other activities; leaching cesspools, or sewers draining into streams or lakes of the catchment area, or into the marginal lands adjacent to them.

4. Improper location of intake with respect to bottom of reservoir and current, or to surface-drainage-water inlets.

5. Intake exposed and accessible to trespassers.

6. For lake supplies: vessels passing near intakes; drift of ice fields; dumping of dredging, garbage, etc., into lake near intakes; inadequate toilet facilities on cribs.

#### **C. SURFACE WATER SUPPLIES, FILTERED**

1. Catchment area: size, topography; population density, sewered and unsewered; surface geology; reservoirs, their capacity and location.

2. Sources of pollution: nature; distance from intake, including miles and rate of flow; amounts and distances of sewered population.

3. Sewage treatment on watershed: extent; methods; population served; effectiveness and uniformity of results.

4. Raw-water characteristics: turbidity, color, alkalinity, hardness, iron, etc.

bacterial quality, average and ranges, variations in quality, especially after heavy rainfall or at times of high run-off.

5. Capacity of filter plant (million gallons per day); rated output, average and maximum daily; maximum capacity of raw-water pumps; standby equipment.

6. Coagulant system: type, as solution or dry feeding; chemicals used; dosage rates, average, maximum, and minimum; number and capacity of units; reserve units.

7. Mixing and flocculation basins: type, flash mixing, average and minimum times; flocculation, average and minimum times; number, size and arrangement of units; provisions for cleaning.

8. Sedimentation basins, number, size and retention capacity; plain sedimentation; postcoagulation sedimentation; methods of cleaning; flexibility of operations; efficiency of turbidity and bacterial removal.

9. Filters: pressure or gravity type; number; sizes and rated capacity, net filtering area; effective size and uniformity coefficient of sand; washing system, direct or from storage, rates of washwater application; loss-of-head gauges; rate controllers, average and maximum rates of filtration.

10. Filtered-water storage: capacity; location; arrangement; covered or uncovered; protection against contamination; methods of cleaning; added storage in distribution system.

11. Aeration: purpose; kind; capacity; location in purification system; efficiency.

12. Disinfection: kind; stages, if more than one; location in purification system; capacity; method of operation; operation control; average, maximum and minimum dosage; chlorine—ammonia ratios, if ammonia is used; simple or “break-point” chlorination, if used; efficiency of each stage; period of chlorine or chloramine contact before delivery.

13. Plant operation and control: technical supervision, trained or untrained, full-time or part-time; number of operators; laboratory control, kind and frequency of tests; plant and laboratory records, kind, extent, use, etc.; meteorological records.

#### *Examples of Sanitary Defects:*

1. Excessive raw-water pollution in relation to extent of treatment provided; existence of nearby uncontrolled sources of raw water pollution.

2. Bypass connections for raw water, or partially treated water, whereby such waters may be discharged into the distribution system.

3. Existence of cross connections, bypasses, or concrete channel walls within plant, such as between conduits or basins carrying untreated or partly treated water, and those containing completely treated water.

4. Lack of reserve capacity of treatment works, necessitating excessive overloading, or occasional bypassing of units.

5. Lack of competent supervision and operation, or of adequate laboratory control.

6. Deficient or inaccurate operation or laboratory records.

7. Lack of suitable devices for measuring and recording volumes of water treated; for maintaining continuity of coagulant and chlorine dosage; deficient retention periods in settling basins; or areas, depths, sizes of sand and washing facilities in filters.



8. Lack of, or deficiency in, proper chlorination equipment and control, or failure to maintain proper chlorine residuals in the treated effluent at all times.
9. Lack of suitable protection for purified water; storage capacity less than requirements for safety.
10. Improper location of water-treatment plant or inadequate protection with respect to flood waters.

#### D. PUMPING STATION AND COLLECTING SYSTEM

1. Location and protection with reference to flooding.
2. Number, type and capacity of pumps, including reserve; condition of equipment and method of operation; condition of suction pipes.
3. Location of suction pipes relative to sources of pollution.
4. Emergency intakes.
5. Emergency supply of power; record of power shut-down; effect of shut-down on surges through conduits, etc.
6. Recording apparatus on suction-well elevation; rise and fall of suction-well elevation.
7. Screens for fish and debris.
8. All sewers cast iron, or otherwise.
9. Curb walls around suction wells to protect against surface drainage.
10. Continuous or intermittent operation.

#### *Examples of Sanitary Defects:*

1. Leaky suction pipes.
2. Pump not self-priming; unsafe water used for priming.
3. Suction well subject to pollution through backflow of polluted water through drain.
4. Suction well or suction pipes unprotected from surface or subsurface pollution.
5. Improper location or inadequate protection with reference to flood waters.
6. Lack of suitable provision for ensuring continuity of pumping service under all possible conditions.

#### E. DISTRIBUTION SYSTEM (EXCLUSIVE OF RESERVOIRS OR STANDPIPES)

1. Area and population supplied, proportion to total within corporate limits.
2. Adequacy of distribution system with respect to area served; sizes of mains and laterals, circulation of water; storage provided.
3. Type of distribution system: whether gravity, direct pumping, indirect pumping, including capacity of pumps, etc.
4. For above-water crossings: flexibility of pipe joints for maintaining tightness under forces due to vibration and temperature changes including freedom of protection of pipe from impact of runaway vehicles, flood waters, and objects carried by flood waters.
5. For underwater crossings: use of flexible watertight joints, provision of valves located above flood level at each end of crossing, duplicate lines, etc.

ment installed for making pressure tests to detect leakage; sampling taps at each end of crossing; provision for blowing off such sections of pipe to waste above ground level; distance pipe is laid below bottom of stream bed.

6. Use of common, or separate, trenches for laying water mains and sewers; practice concerning crossings of water and sewer lines.

7. Disinfection procedure followed in laying new mains, or repairing existing mains.

8. Method of draining hydrants: sewers, dry wells, ground surface, other.

9. Elevation of booster-station floor level with regard to ground level; location of booster-pump suction lines relative to sources of pollution; possibility of developing negative heads in booster-pump installations drawing directly from the distribution system.

10. Method of delivery of water from public supply to some other water system which uses unsafe water.

11. Adequacy of piping system for maintenance of positive pressure in all parts of the distribution system, under normal usage, at all times.

#### *Examples of Sanitary Defects:*

1. Existence of cross connections between primary supply and secondary supply of questionable safety at any point in the distribution system.

2. Return to the system of any water used for cooling; hydraulic operations, etc. (This is not intended to rule out the use of the barometric-type condenser, or an entirely closed cooling circuit, at the water-supply plant.)

3. Absence, or inadequacy of, protection; lack of covers, improper location of distribution reservoirs, standpipes, or elevated pressure tanks.

4. Intermittent service, resulting in reduced or negative pressures in distribution system; sizes of mains and laterals inadequate for preventing negative pressures; presence of dead ends permitting reduced or negative pressures.

5. Connections to sprinkler systems using toxic solutions, such as antifreeze.

6. Repumping on consumer premises when pressure is low, causing negative head.

7. Connection to sewers and sewer-flushing chambers, and improperly located blow-offs in distribution system.

8. Existence of hydrant drain lines connected to sewer.

9. Presence of a secondary nonpotable water system on premises where a public system exists, unless adequate regulations and enforcement are provided to prevent the occurrence of cross connections.

10. Lack or inadequacy of enforcement of plumbing regulations and/or ordinances designed to protect the water supply against the possibility of backflow from plumbing fixtures or from mechanical equipment supplied with water from public water supply.

11. Connection of new pipe lines to the system without prior disinfection of pipes.

12. Existence of tile, or other leaky pipes, in distribution system.

13. Improper location of water pipes in relation to sewers and storm-water mains.



## F. STORAGE (RESERVOIRS ON DISTRIBUTION SYSTEM)

1. Use, location, and capacity of reservoirs and standpipes.
2. Reservoir sites, protection from trespassers; location with respect to sources of pollution; character of local geology.
3. Hazard of entry of flood and drainage waters; elevation of top of storage units with respect to highest known water level of any lake, pond or stream, the waters of which might approach storage units; precautions taken to divert surface drainage from the storage units; water tightness of reservoir or storage unit.
4. Point of discharge, as sewers, ground surface, etc., of overflows, blow-offs, clean-outs, and drains from roof or bottom of water-storage units.
5. Elevation above ground level of walls of surface storage units.
6. Protection of valve pits for storage units against flooding and surface drainage, and point of discharge of drains therefrom.
7. Type of cover or roof, manholes, vents, overflows, control gauges, and character of pipe connections to reservoir with regard to danger of leakage at points of entry.
8. Disinfection practice for new reservoirs or after cleaning and repairs on existing units.

*Examples of Sanitary Defects:*

1. Presence of earth formations at the reservoir site such as limestone, broken lava rock, coarse gravel, etc., whose interstices are in the form of channels, joints, or fissures and hence provide too little filtering action to prevent contamination from reaching the reservoir; poor surface-drainage conditions; insufficient distance from bodies of surface water or sources of contamination; top of reservoir not above ground or above level of flood waters.
2. Unsatisfactory materials, poor state of repair, cracks, lack of proper covers, vents and overflows that do not exclude birds, dust, rain, insects, etc.
3. Water-level indicators and control gauges that permit entrance of contamination into stored water.
4. Curbing or roof coping interfering with roof drainage.
5. Manholes and covers of flush type, and covers or manholes which permit leakage of drainage into the reservoir or storage unit.
6. Drains from reservoirs to sewers or surface waters when backflow therefrom can reach reservoir.
7. Valve stems projecting through reservoir covers not protected.

The field examination, when properly made and repeated at intervals, furnishes information of the sanitary and hygienic aspects of a water supply of greater significance than that obtained in any other way. It secures not only collateral evidence to be used in the interpretation of laboratory findings and morbidity statistics but also brings together facts which indicate the hazards under which the supply is operating. Further, these facts form a basis for prediction of changes to come. They show the trend of conditions and are a guide in shaping plans to meet future contingencies.

**Laboratory Examination.** A sanitary analysis is intended to furnish evidence of the wholesomeness of water and its general fitness for domestic and permitted industrial uses. The analysis of water is unlike that of most other substances in

that many of its constituents have no great significance of themselves but acquire significance only in relation to other information. It is also a fact that waters of acceptable quality differ greatly from each other and that the same water supply may show wide fluctuations in quality from season to season. This is particularly true of surface supplies. The interpretation of laboratory findings needs to be made in the light of all the analytical data obtainable and with the guidance of supplementary information from every possible source. When this is done the laboratory becomes an invaluable adjunct for estimation of sanitary quality.

Great stress should be laid upon the frequency of analysis. A single examination gives but little information, since it provides no indication as to whether or not the sample is truly representative. Only when examinations are made at regular and frequent intervals can well-founded conclusions be drawn. Frequency of analysis is a matter of judgment, and depends on the purpose of the analysis, the observed fluctuations in water quality, and the nature and magnitude of possible health hazards present. The report on drinking water standards of the U. S. Public Health Service (1946) contains suggestions as to the frequency of sampling for bacteriological analyses.

Laboratory examination is indispensable to the design and operation of water purification plants. It is the only means by which the performance of the purification processes can be evaluated and controlled. The degree of contamination in the raw water and the extent to which it is removed by purification processes can best be judged by tests in the laboratory. Laboratory analyses also indicate trends and changes, and are useful in forecasting future conditions which purification processes will have to meet.

Thus, although sanitary analysis is second in importance to the field survey, it is an indispensable part of the work of establishing and maintaining a safe water supply. It corroborates or modifies estimates of quality made in the field and indicates, within the bounds of present knowledge, the probable results of use of the water.

## STANDARD METHODS

If the results obtained from analyses of collected samples by different analysts are to be comparable, and subject to uniform interpretation, the procedures used must be standardized. A standing committee on Standard Methods of Water and Sewage Analysis is maintained by the American Public Health Association, with the cooperation of the American Water Works Association and the Federation of Sewage Works Associations. This committee produces, at suitable intervals, a revised edition of *Standard Methods of Water Analysis*,\* which contains the accepted methods for chemical and bacteriological analyses of water. These methods are periodically checked by the committee, and improvements and alterations are made as experimental work confirms their desirability. Analyses made by the procedures described in *Standard Methods* are recognized by the courts and are universally used by analysts responsible for the control of public water supplies. Such standardization does not preclude the development of new and improved methods, or the use of special technics for special investigations. Its purpose is to establish a

\* The full title of the tenth edition (1955) is: *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*.



recognized norm of procedure which conforms to the best in current analytical practice.

**The Parts of a Sanitary Analysis.** A sanitary analysis of water resolves itself into four component parts: (1) physical, (2) chemical, (3) microscopic, and (4) bacteriological examinations.

**PHYSICAL TESTS.** Physical tests have to do with the determination of substances which affect the physical or esthetic quality of water, such as taste, odor, color, and turbidity. These tests are likely to be empirical and arbitrary in method and form of expression. It is difficult to express the results in terms of the amounts of specific compounds present, for any of the above-mentioned qualities may be due to a variety of compounds, many of which are of complex, organic structure and some incapable of detection by present laboratory methods. The technics employed for the physical examination attempt to evaluate the total effect of all compounds present which can be measured by the sense of taste, smell, or vision.

**CHEMICAL EXAMINATION.** The chemical examination is made by special technics of analytical chemistry adapted to measure the relatively small quantities of substances present in water. Some of these technics directly determine specific substances, others are indirect, and measure the total effect of a complex of ingredients. The chemical examination is of some value in detecting pollution, but its principal contributions are data concerning the chemical quality of the water, the effectiveness of purification processes, and the previous history of the water.

**MICROSCOPIC EXAMINATION.** The microscopic examination is designed to detect and measure the quantities of algae, protozoa and related organisms of the same order of magnitude. These organisms are of importance to the analyst as frequent sources of odors and tastes as well as of scums and water blooms. Dead organisms and amorphous matter may also be included.

**BACTERIOLOGICAL EXAMINATION.** The bacteriological examination deals with the numbers and kinds of bacteria present. From its findings a better appraisal of hygienic quality can be made than from any other part of a sanitary analysis. It has been possible from experience to define more closely limiting values for bacteria, particularly the coliform group, than for other constituents of water.

**CORRELATION.** From the foregoing it will be noted that each of the four parts of a complete sanitary analysis deals with different, although often complementary, qualities of the sample. It is, therefore, of prime importance that any estimate of character and quality which is based upon laboratory findings should be made in the light of all the tests assembled and correlated.

**Collection of the Sample.** For a complete physical, chemical and microscopical analysis of water one gallon is necessary. If the sample has been collected in a sterile container with precautions to prevent contamination the same sample may serve for the bacteriological examination. Usually the bacteriological samples are collected separately in special bottles holding at least 100 ml., but not completely filled.

The bottles for bacteriological samples should be of hard, clear white glass and have a glass stopper or other closure which will resist the high temperature necessary for sterilization. Cork stoppers are not satisfactory. The bottles should be chemically clean and sterilized in an oven at 170° C for one hour, or in an autoclave at a steam pressure of 15 pounds for 15 minutes. For transportation the neck

may be covered with tinfoil, cloth, or heavy paper before sterilization and the bottle placed in a tin box. Earthen jugs and metal containers are entirely unsuited.

Samples for physical, chemical and microscopic analyses should also preferably be collected in bottles of good glass with glass stoppers or plastic closures. Cork stoppers covered with tinfoil or paraffin may be substituted when only mineral analyses and physical examinations are to be made.

Generally speaking, the shorter the time elapsing between collection and analysis, the more reliable will be the analytical results. The bacteriological results are especially sensitive to delay, since bacteria may multiply or diminish in the bottle. Best results are secured if the bacteriological samples are transported and stored at refrigeration temperatures. The oxygen consumed, the oxygen demand, the pH value, and the nitrogen determinations are also materially affected by comparatively short delay. The dissolved gases should be determined at the source. The following are the maximum times which may elapse between sampling and analysis (American Public Health Association, Standard Methods for the Examination of Water and Sewage, Tenth Edition):

#### PHYSICAL AND CHEMICAL ANALYSIS

Unpolluted water . . . . .	72 hours
Fairly pure waters . . . . .	48 hours
Polluted waters . . . . .	12 hours
Sewage and sewage effluents . . . . .	As soon as possible
	Store at 3° to 4° C

Preservation by sterilization with acid or a germicide will permit longer delays. Procedures depend on the determination to be made.

#### BACTERIOLOGICAL ANALYSIS

Pure waters . . . . .	12 hours
Impure waters . . . . .	6 hours
Samples to be kept between 0° C and 10° C	

Samples for microscopic analysis are preferably examined in the field, especially if fragile organisms are present. Under no circumstances should the elapsed time be more than 12 to 24 hours of refrigerated storage.

**Technic of Sampling.** Care should be taken to secure a sample thoroughly representative of the water to be analyzed. A pump should be operated five minutes, a water faucet allowed to run several minutes, before the bottle is filled. In collecting samples of surface waters the specimens should not be obtained too near the bank of the stream or pond and surface pollution should be avoided. If the sample is not collected from the surface, a note should be made of the depth at which it is taken. It is always advisable to take the temperature of the water at the time of collection.

**Expression of Chemical Results.** Use of a measured volume of water underlies most analytical procedure. Results are expressed in milligrams per liter (mg./l.) or in parts per million (p.p.m.); these are substantially identical since a liter of water weighs very nearly 1,000 gm.

When water is highly mineralized analytical procedures may be based on a



known weight of water, or the weight may be estimated from the known specific gravity and volume.

The concentration of chemicals, such as alum and lime, that are added to water for treatment purposes, is commonly expressed in grains per gallon. One grain per U. S. gallon is equivalent to 17.1 parts per million, and, since the Imperial gallon is 1.2 U. S. gallons, one grain per Imperial gallon corresponds to 14.25 parts per million.

### PHYSICAL TESTS

**Odors and Tastes.** Although the taste of a water seldom bears any relation to its safety, to the ordinary consumer it is probably the most important property of a water supply. No amount of scientific evidence that the water is free from anything injurious to health will suffice to allay the suspicion aroused by unpleasant or unusual flavors. It has been demonstrated many times that a safe but unpalatable supply will be abandoned by many in favor of a palatable water of dubious sanitary quality.

The sources of the odors and tastes which occur in potable waters are numerous; some of them are as yet imperfectly understood, but most of them can be controlled or at least mitigated. The true tastes, namely, the salty, sour, sweet, and bitter flavors, are comparatively rare in water supplies. Where they occur, they are generally due to excessive amounts of dissolved salts, acid or alkaline substances, iron compounds, and a few other less well identified agents. Tastes are sometimes produced as a result of improper or excessive chemical treatment of water. Most of what are called "tastes" in water are in reality odors; they represent the response of the olfactory centers to substances volatilized from the water in the course of ingestion.

The most common cause of objectionable odors in water supplies is the presence of microscopic organisms. The principal offenders are members of the following groups: green and blue-green algae, diatoms and protozoa. Recently, suspicion has also been directed toward the actinomycetes. Odors may also develop from the decay of organic matter in the absence of oxygen as, for example, in the lower depths of impounded reservoirs. Well waters in certain regions may contain hydrogen sulphide; the resulting odor is highly objectionable. Industrial wastes are often responsible for odors. For example, certain wastes from the beet-sugar industry produce objectionable flavors in water even when present in very small amounts.

Chemical treatment of water often produces objectionable flavors. The single outstanding defect of chlorine as a disinfecting agent is its tendency to alter the flavor of the water for the worse. Excessive chlorination results in a product in which the odor of chlorine itself is objectionable to many consumers. More frequently, however, the chlorine reacts with substances present in the water to produce odors of other types; a notable example is the iodoform or medicinal taste produced by the action of chlorine on water containing even a few parts per billion of phenolic substances. Other chlorine reaction products result in tastes often described as "woody." Used judiciously, in accordance with modern practice, chlorine does not necessarily produce such taste and odor problems, and may even eliminate many tastes and odors from other sources, but careful control of chlorination is an absolute necessity if a palatable water is to be secured.

**DETERMINATION OF ODOR.** The odor of a water should be observed both at room temperature and at 50° to 65° C. The kind of odor observed may be described as vegetable, aromatic, grassy, fishy, earthy, moldy, musty, disagreeable, peaty, sweetish, etc. The intensity may be estimated, or it may be determined semiquantitatively by serial dilution with odor-free water—the so-called threshold odor test.

**ODORS DUE TO MICROSCOPIC ORGANISMS.** The odors and tastes in water caused by microscopic organisms deserve special consideration, because they are common faults in water stored in open reservoirs of all kinds. Certain organisms can be distinguished by their odor, as, for example, the “fishy” odor of *Uroglenopsis*, a member of a group of motile, chlorophyll-bearing organisms (Chrysophyceae) often included in the protozoa; the “aromatic” or “rose-geranium” odor of *Asterioella*, which belongs to the Bacillarieae; and the “pig-pen” odor of *Anabaena*, which is one of the blue-green algae (Whipple, 1927). Most of these microscopic organisms grow near the surface and require sunlight for their development; hence, they do not grow in covered reservoirs or in waters kept in the dark.

Calkins has shown that the odors caused by the undecomposed microscopic organisms are due to compounds of the nature of essential oils, and Whipple points out that the amount of such oil produced by an abundant growth of the organisms is quite sufficient to account for the effect observed. Whipple further suggests that the flow of water through pipes may cause disintegration of organisms with liberation of the odor-producing oil, hence the odor at the tap may be greater than at the intake.

The micro-organisms causing bad tastes and odors in water are mostly chlorophyll-bearing forms, which do not depend upon organic matter or the bodies of other organisms for their food supply. They require only sunshine, carbonic acid and the nitrates and minerals always present in the water and in the air. In other words, they have properties comparable to the higher orders of chlorophyll-containing vegetation. Many of them, however, resemble animals insofar as they possess a high degree of motility.

There are many kinds of algae, and they differ greatly in their odor-producing powers. Most American impounded reservoir waters suffer from them.

A certain degree of quiet and repose is necessary for the development of a large growth of algae; that is why they rarely develop significantly in rivers and flowing water. Wave action also prevents growth, and this seems to be the reason why large lakes and reservoirs are less troubled by them than smaller ones.

In most American impounded reservoirs the water is drawn from near the surface layer, so as to avoid the odors and tastes of putrefaction in the bottom water, but it sometimes happens that the surface is the more objectionable because algae grow there. For this reason a water-intake should preferably permit shifting depth from which water is drawn.

**PREVENTION AND REMOVAL OF TASTES AND ODORS.** Odors can be reduced, but almost removed, by aeration. Natural aeration takes place during turbulent flow over stones and ledges. Aeration may also be accomplished in water treatment plants by devices such as nozzle fountains and cascades. The reduction in odor accomplished by such devices depends on the type of odor present; for algal odors the expense of aeration is rarely justified. The degree of removal also depends upon



the thickness of the water films brought into contact with the air and upon the time allowed for contact.

Some reduction of odor is accomplished by filtration. Chlorination for disinfection often intensifies odors, either by destruction of algae and release of their odor-producing substances, or by reaction with organic substances to produce compounds of greater odor intensity. Such intensification can be avoided by the use of ammonia along with the chlorine, to reduce the reactivity of the latter. Complete destruction of odor can often be accomplished by a very heavy dose of chlorine which completely oxidizes odoriferous organic substances, and is itself partly destroyed in the process. The surplus of chlorine can be eliminated by dechlorinating agents, such as sulfur dioxide, or the chlorine dose can be adjusted to leave a slight residual, the so-called "break-point." The use of chlorine dioxide in place of, or in conjunction with, chlorine shows promise as a means of destroying tastes and odors.

One of the most effective methods of removing tastes and odors makes use of activated carbon, a charcoal prepared from various materials and subjected to special treatment to enhance its adsorbing power. The water may be filtered through beds of granular activated carbon, but the usual and more effective practice is to add powdered activated carbon to the water in the course of the rapid sand process of filtration. The carbon is removed as the water passes through the coagulation basins or filters. It adsorbs organic substances and the odoriferous oils of the algae. It is highly efficient as a taste or odor *remover*, as well as being a *preventive* of these qualities by reason of its ability to take out foreign substances which might react with chlorine when the latter is applied for final disinfection. For further information on the ammonia-chlorine, break-point, chlorine dioxide, and activated carbon treatments see Chapter 39.

It is practically impossible to prevent the seeding of reservoirs and ponds with algae and other organisms responsible for the objectionable odors. The growth may be checked and the odors temporarily controlled by the use of copper sulfate (see Chapter 39).

If a well develops odors from putrefying organic matter collected on the bottom, the trouble may be corrected by cleaning out the well thoroughly, or by filling up all unnecessary space below the suction pipe with clean gravel and sand.

**Color.** Pure water, such as distilled water, when viewed in shallow depths appears to be perfectly colorless, but, when viewed in bulk, it is seen to possess a beautiful greenish-blue tint. A small amount of suspended or dissolved impurity is sufficient to modify or obscure this color.

Most surface waters exhibit a color varying from green to yellow and brown when examined through a depth of several inches in clear glass tubes.

Color in surface water is usually of vegetable origin; animal matter contributes but little color. The coloring matter is extracted from dead leaves, bark, and roots, from soil and from peat. It is similar to the coloring matter of tea. It is certainly harmless, but makes water less pleasing in appearance, and great efforts are made to prevent and remove it. Water from swamps is usually brown-colored. Colors may also be due to the presence of industrial waste, unlike natural colors which tend to be of approximately the same hue, the colors due to industrial

waste vary greatly in hue and intensity and no standard method for their measurement is available.

Ground waters are usually colorless. If the water contains iron it will be perfectly clear on coming from the ground, but will soon turn a rusty yellow color. This is caused by the oxidation of the soluble ferrous salts to insoluble ferric salts.

**DETERMINATION.** The natural color of water is determined by matching a 50- or 100-ml. sample in a Nessler tube with a standard solution of platinum and cobalt salts. The primary standard, containing 1.425 gm. potassium chloroplatinate and 0.1 gm. cobaltous chloride per liter, is assigned a color value of 500 p.p.m. This standard is diluted to give subsidiary standards of suitable range for comparison with the sample. The comparison is made by looking vertically downward through the tubes upon a white surface placed at such an angle that light is reflected upward through the column of liquid.

**PREVENTION AND REMOVAL.** Excessive color in surface water can be partially controlled by preventive measures on the watershed. These consist of the drainage of swamps and the stripping of the shore line. In the construction of impounding reservoirs heavy deposits of muck and organic matter are removed or covered with gravel and sand before the reservoir site is flooded.

Color is reduced by storage in reservoirs. The action is the result of several forces. To some extent there is a bleaching action and oxidation due to exposure to sunlight and air, but it is probable that physical forces play the major role and operate to bring about a coagulation of colloidal color particles which gradually precipitate.

Color is removed from water by coagulation with aluminum sulphate or occasionally with iron salts, followed by sedimentation and rapid sand filtration. At many plants nearly complete removal is obtained. Other methods for removing color, such as oxidation by chlorine, are possible, but their cost is greater than that of coagulation and filtration, so that they are not in use. The drinking water standards of the U. S. Public Health Service (1946b) limit color in filtered waters to 20 parts per million.

**Turbidity.** Practically, turbidity is synonymous with muddiness. It is that property which interferes with the distinctness with which the outline of objects is seen through water. The turbidity of surface waters is usually due to mud, clay or silt, but it may also be due to a variety of other substances, such as finely divided organic matter or microscopic organisms. Many industrial wastes contribute large amounts of turbidity. Turbidity measures the amount of foreign substances in suspension. Turbidity and color do not generally occur together in large amounts; the former presents the washings of a readily eroded drainage basin, the latter is mostly extracted from the decaying vegetation of swamps.

Clean water is clear and sparkling, but brilliancy and clearness do not guarantee freedom from contamination, nor, on the other hand, does turbidity necessarily indicate danger. The turbidity problem is practically limited to river waters. Ground waters should seldom be turbid and, if so, should at once excite suspicion. Some ground waters become more or less turbid through the precipitation of iron through the failure of supporting strata which allows entrance of clay or soft rock material to the water.

All river waters are more or less turbid, but the differences are great indeed.



The amount of turbidity depends largely upon the character of the catchment areas. In general, rivers draining the large areas of our North and East which are covered with glacial drift of a sandy character, carry less than 10 p.p.m. of turbidity, unless they are polluted by sewage and industrial waste. In that part of our country which is not glaciated—for example, the lower Susquehanna basin, much of the Ohio basin, and the Missouri basin—turbidity is often present in large amounts, and consists largely of finely divided clay. The Missouri River carries an annual average of 1,200 or 1,500 parts per million of suspended matter. In winter it falls to 200 parts or less, while in midsummer it rises for weeks and even months to 5,000 parts or more.

Turbidity is ordinarily removed by coagulation, sedimentation, and rapid sand filtration. The coagulants and procedures are substantially the same as those used to remove color, but the required dosages and the optimum pH range for coagulation are often different. One of the principal factors contributing to the obsolescence of the slow sand filter is its inability to handle waters containing any substantial amount of turbidity. Occasionally, very turbid waters may be given a preliminary period of sedimentation, to reduce the load on the coagulation and filtration process. This procedure succeeds only if a fair proportion of the turbidity is comparatively coarse, and is becoming rare in practice. Even less common is the use of preliminary rapid filters, or scrubbers, used without coagulant to protect slow sand filters, as, for example, in the purification plants of the London Metropolitan Water Board. The turbidity in the London supply is due primarily to algae. Even here the use of scrubbers is conceded to be obsolete, and other methods, such as fine screening, are being investigated.

There is no evidence that natural turbidity is harmful in any way, although this may not necessarily be true of turbidities caused by industrial wastes. For filtered waters the U. S. Public Health Service (1946b) drinking water standards specify a limiting turbidity of 10 parts per million, but for unfiltered waters the limit is a matter for judgment based on local conditions. Obviously, the reasons for setting a low limit for filtered water relate to esthetic considerations, and to the effectiveness of the filtration plant in removing truly harmful substances.

Low degrees of turbidity may be accurately determined by the comparison of a sample with standards in clear glass bottles or long glass tubes, prepared by dilution of a standardized suspension of fuller's earth with distilled water. For high turbidities a turbidimeter gives satisfactory results. Jackson's turbidimeter employs a calibrated glass tube, into which the sample is poured until the image of a standard candle flame below the base of the tube is obscured.

#### CHEMICAL EXAMINATION

**Total Solids.** The concentration of total solids or residue on evaporation is obtained by evaporating a given quantity of water to dryness, whereupon a grayish-white residue, composed of the mineral and organic matter which has been held in the water in suspension and in solution, will be obtained. The amount of this residue varies with the character of the water. If the total residue is ignited, the "loss on ignition" is a rough index of the total amount of organic substances present. The residue remaining after ignition consists of mineral matter and is an index of the inorganic matter in the water.

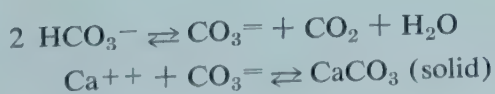
The amount of total solids in a water depends upon the character of the soil and rocks with which the water has been in contact, the length of exposure, and the amount of carbon dioxide in the water to favor the solution of inorganic salts. Some mineral springs contain very large amounts of total solids, derived from deeply situated natural deposits. The springs at Saratoga are an example.

The permissible amounts of total solids cannot be arbitrarily stated, but the drinking water standards of the U. S. Public Health Service (1946b) recommend that they should not exceed 1,000 parts per million and should preferably not be over 500. From a sanitary standpoint the problem is not alone quantitative, but also qualitative.

**Hardness.** Hard water is objectionable because it wastes soap and affects the skin unpleasantly; it is less satisfactory than soft water for cooking and washing; it produces scale in boilers and is objectionable in many industries, such as textile and paper mills. However, with the advent of synthetic detergents, some of the objection to hard waters for domestic use has been eliminated. There is a general belief that abrupt change from soft to hard water, or vice versa, will cause temporary gastrointestinal disturbances, but no clinical evidence exists. There is likewise no evidence that hard water as such, has any other influence on health, either favorable or adverse. However, it is true that waters containing substantial amounts of magnesium ions associated with sulphate ions will produce laxative effects in persons unaccustomed to them. Hardness in water is, therefore, primarily an economic question.

Hardness in water is due to the presence of the soluble salts of the alkaline earths, especially calcium and magnesium. These salts form a curd with soap, hence soap must be consumed in precipitating the calcium and magnesium ions before lather will form. In this way hard water causes an enormous waste of soap. In this country hardness is expressed in parts per million of calcium carbonate, or in grains per gallon of calcium carbonate. In Europe, hardness is usually expressed in degrees. One English degree of hardness corresponds to one grain of carbonate lime in an Imperial gallon of water.

The hardness of water is of two kinds, "carbonate" and "noncarbonate." Either both may be present. *Carbonate hardness* is that portion of the calcium and magnesium ions which is chemically equivalent to the carbonate and bicarbonate ions present in the water. This is sometimes more simply expressed by saying that it consists of carbonates and bicarbonates of calcium and magnesium; but the statement, although convenient in practice, is scientifically inaccurate. Most natural waters contain dissolved  $\text{CO}_2$ , in the presence of which carbonates become bicarbonates, so that carbonate hardness is usually due to bicarbonates. This form of hardness is sometimes called "temporary" because boiling will drive off  $\text{CO}_2$  from causing most of the bicarbonate ion to be converted to normal carbonate ion. As soon as the product of the calcium and normal carbonate ions exceeds a fixed value, solid calcium carbonate is formed. The reactions are shown below; they are reversible:





*Noncarbonate hardness*, on the other hand, is that portion of the total calcium and magnesium ions in excess of the equivalent amounts of carbonate and bicarbonate. It is frequently but inaccurately referred to as calcium and magnesium sulphate, chloride, etc. It is sometimes called "permanent hardness" because it does not precipitate on boiling. Both carbonate and noncarbonate hardness contribute to scale in steam boilers.

Waters containing less than 50 parts per million of hardness may be considered soft; those containing more than 150 parts, hard. Usage largely determines the degree of satisfaction with which waters of different amounts of hardness are received, although standards are rapidly changing and there is a popular demand that very hard waters be softened. In the lake cities, 100 parts per million is considered satisfactory, yet such a hardness in eastern cities, where values are generally under 50 parts per million, would be a cause of complaint.

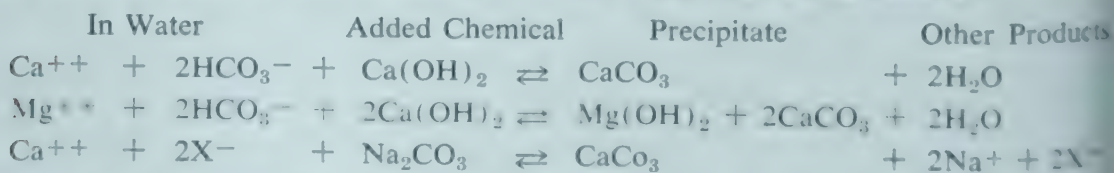
Rain water is always soft; surface waters vary, but are usually not very hard; ground waters are more apt to be hard.

Two conditions must be present to make a ground water hard: first, the material through which the water passes must contain calcium or magnesium salts; and, second, the conditions must be favorable for dissolving them. If the calcium and magnesium are present in the soil as the carbonates, any carbon dioxide present in the water will dissolve them, by reversing the reactions given under the discussion of temporary hardness.

As a result, waters drawn from limestone regions vary greatly in hardness. Rain water contains but little carbonic acid and, therefore, has little power of dissolving limestone. The principal source of the carbonic acid in ground water is from the decomposition of organic matter in the soil. The hardness of water, therefore, depends more upon the nature of the catchment area than upon the amount of lime in the various materials over which the water flows.

**SOFTENING OF WATER.** There are two methods of softening water in general use, the lime-soda or Clark-Porter process, and the ion-exchange or Zeolite process.

In the lime-soda process, hydrated lime and soda ash (sodium carbonate) are added to the water to precipitate, respectively, the carbonate hardness and the magnesium, and the remaining noncarbonate hardness. The precipitate is settled out, and the water is then filtered. The basic equations are as follows:



where X represents any ion other than carbonate or bicarbonate. Given the calcium (Ca), magnesium (Mg), and bicarbonate content (alkalinity) of the water all expressed as calcium carbonate, the chemical dosages required to soften a water can be computed from the following equations, derived from the chemical expressions above:

Lb. lime as CaO per million gallons =  $4.66 (\text{Mg} + \text{alkalinity})$

Lb. soda ash as  $\text{Na}_2\text{CO}_3$  per million gallons =  $8.83 (\text{Ca} + \text{Mg} - \text{alkalinity})$

In these equations the terms Ca, Mg, and alkalinity are all expressed as parts per million of calcium carbonate.

As carried out in municipal water softening, the lime-soda process can reduce the hardness of a water to about 75 parts per million; special variations of it, such as excess treatment, or softening the water after heating, are used in industrial practice, and permit reduction of hardness to about 30 parts per million.

The ion-exchange process is based on the ability of certain natural and synthetic materials to remove from water the objectionable calcium and magnesium ions, and substitute for these, less objectionable ions, such as sodium. The exchange materials then can be regenerated for further use by treatment with a strong solution of sodium chloride. The reactions are as follows:



In operation, the water to be softened is passed through a bed of the exchange material in granular form, which removes the hardness. When the bed is exhausted, it is treated with a 5 to 10 per cent solution of salt to regenerate it, rinsed to free it from the salt, and is then ready to soften more water. The operation can be made completely automatic. The ion-exchange method can reduce the hardness of the treated water substantially to zero, but this is undesirable in practice, since such water is highly corrosive; it is usual to by-pass a portion of the water around the softener, producing a blended water containing some residual hardness.

There are three general types of ion-exchange materials. The first ones used were naturally-occurring silicate minerals, variously called greensands, glauconites or zeolites; they are still valuable because of their high durability, although their capacities are relatively low. Synthetic siliceous materials, called gel zeolites, have high capacities but are less resistant to attack by chemical substances in the water. The comparatively new organic ion exchangers are made from carbonaceous materials treated with fuming sulphuric acid, or from synthetic resin-like polymers. These organic exchangers combine high capacity and resistance to chemical attack and are tending to replace the other two types.

The organic ion-exchange materials are capable of replacing all positive ions in the water by hydrogen ions if they are regenerated with acid rather than with alkali. This makes possible the complete demineralization of water; a second bed of exchange material, called an anion exchanger, removes the hydrogen ions, and also takes out nearly all the negative ions, such as chloride, sulphate, etc. The anion exchanger is regenerated with soda ash or caustic soda. Water treated by this two-stage exchange process is substantially equivalent to distilled water; the process has considerable application in industrial water supply, and is beginning to be used to produce potable water from waters containing excessive salinity.

**Alkalinity and Acidity; pH Value.** Most natural waters contain bicarbonate ions; occasionally normal carbonate ions are present. All waters contain the hydroxyl ion, but the amounts are negligible except in waters which have received strongly alkaline wastes, and in waters which have undergone certain types of treatment. The presence of these ions causes the water to have an alkaline reaction with respect to methyl orange indicator, and occasionally to phenolphthalein indicator. The quantity of standard acid required to render the water neutral to these



indicators is a measure of the quantity of the ions mentioned above present in the water; this quantity is called the alkalinity of the water, and is expressed in terms of equivalent calcium carbonate. The alkalinity of a water, in relation to its hardness, determines the proportions of "temporary" and "permanent" hardness, and also determines the amounts and kinds of chemicals necessary for softening. It has an important bearing on the corrosiveness of the water; a water having a high alkalinity is generally less corrosive than one of low alkalinity. It is of significance in determining the method used for coagulation of the water prior to rapid sand filtration.

Waters from mining regions, and rain waters collected in the vicinity of cities may sometimes contain little or none of the ions comprising alkalinity, but instead may have considerable quantities of acids, principally sulphuric. The measurement of acidity is analogous to that of alkalinity; methyl orange indicator is used, and a standard base is substituted for the standard acid. Acid waters are difficult to handle; they are highly corrosive, and the acid must be neutralized by the addition of lime or other alkali before they can be used in water supplies.

The alkalinity and acidity of waters are measures of the total quantities of substances capable of reacting with acid or alkali. The intensity factor, which corresponds to these quantity factors, and which determines the behavior of the water, is called the pH value. It is a measure of the hydrogen ion activity in the water, but since the actual quantity is small, it is more conveniently expressed as the logarithm of the reciprocal of this activity. The scale runs from zero, representing a highly acid solution (one normal acid) to 14, representing a highly alkaline solution (one normal base). A completely neutral solution has a pH value of 7.0; a water having this pH value has neither an acid nor an alkaline reaction, although it may contain considerable amounts of "alkalinity." Most natural waters have pH values which range around 7.0; the usual limits are about 5.5 to 8.5, although exceptions can be found. Treated waters may have values outside this range; the U. S. Public Health Service drinking water standards permit pH values as high as 10.6.

The pH value of a water is determined by the chemical equilibria which are set up between hydrogen ions and the various acid and alkaline substances present in the water; in most waters, the principal determinants are the proportions of carbon dioxide (carbonic acid), bicarbonate, normal carbonate, and hydroxyl ions. The relationships between pH value and these components may be computed by solving the equations which govern these equilibria (Moore, 1939).

The pH value of a water is one of its most important properties. Taken together with the alkalinity and hardness, it determines the corrosiveness of the water, it is probably the most important factor in the behavior of the water toward coagulants, and it has great influence on the effectiveness of the disinfection procedures applied to the water, especially on chlorine disinfection. Although it has no direct sanitary significance, its marked effect on all phases of water supply and treatment makes it an essential part of a sanitary water analysis.

**Chlorides.** Chlorine in the form of chloride ion is a normal constituent of all waters. Traces taken up from the air are found in rain water, especially near the sea-coast. The chloride in surface and ground waters comes from the mineral deposits of the earth, from the ocean vapors and spray carried inland by the wind, and also from polluting materials like sewage and trade waste, both of which are likely to contain

the common salt used in the household and in manufacturing. The chloride content of urine is high. A comparison of the chloride content of a water with that of other waters in the general vicinity known to be unpolluted may afford useful information.

The amount of chloride in water is determined by titration with standard silver nitrate, using potassium chromate as an indicator for the end point.

Before the water analyst is able properly to interpret the significance of the chloride content of a water it is necessary to know the normal amount of chloride present in the waters of that locality. The amount of chloride in a water of a district varies with several factors, such as the distance from the sea, the amount of rainfall, the amount of evaporation, and the direction of the winds. An increase over the normal is an indication of pollution. While the ammonia and the nitrites may have disappeared and the nitrates may have been largely taken up by growing vegetation, the chloride, which is exceedingly stable, will be left to indicate remote or past pollution.

The admixture of even a small proportion of sea water renders water hard and salty and undesirable for domestic use. It also renders water unsuitable for use in boilers. Wells driven near the sea frequently become contaminated with sea water, particularly if sufficient water is withdrawn to allow sea water to work back into the wells as an undercurrent. It then gradually mixes with the fresh water above and sooner or later appears in the well water. When this happens it may be a difficult matter to operate the well so as to avoid drawing sea water. In wells near the sea it is important to draw no more fresh water than would otherwise flow to the ocean. The yield of such wells is therefore limited.

With regard to the consumption of waters made saline by admixture of sea water or by contact with underground salt deposits, there is no present evidence that such waters are injurious to the health of normal persons, at least up to a salt concentration of 4,000 p.p.m. However, such waters possess a taste objectionable to most consumers at levels of 500 to 1,000 p.p.m. of salt, and if neutral salts other than sodium chloride, such as sodium sulphate or magnesium sulphate are present in appreciable amounts, they may have a laxative effect on new consumers. They are also corrosive and unsatisfactory for industrial uses. Because of the difficulty and expense of removing these neutral salts from water, it is better to avoid them if nonsaline sources are available. The removal of salts from water by distillation is discussed in the section on water purification. As previously noted, the use of ion exchange is a possibility. However, the costs of both processes are very high, and they are employed only where saline waters are the only ones available.

**Iron.** The iron content of water, although it has no bearing on health, is of great importance with respect to its appearance, palatability, and suitability for domestic and industrial uses. All natural waters contain a certain amount of iron, and ground waters are likely to contain it in objectionable quantities. No water can be considered entirely satisfactory that contains more than 0.3 part per million parts of iron. More than this renders water unsuitable for domestic and technical purposes; it stains clothes in the laundry, clogs pipes, interferes with industrial processes and forms sludge in boilers.

When iron is present in water it may support filamentous bacteria such as *Sphaerotilus*. This organism may grow in pipes in sufficient amounts to obstruct the flow of water or even completely choke them. This sometimes occurs in the



pipes of driven wells. It is chiefly troublesome in ground waters containing organic matter and iron.

Iron is widely distributed and exists in practically all sands, gravels, soils and rocks with which water comes in contact. The solution of the iron is partially brought about by the organic matter. The iron exists in the soil both as ferrous and as ferric compounds. The latter are reduced by the organic matter to ferrous salts, which are soluble in water containing carbonic acid. The iron is dissolved as ferrous ion, usually in association with bicarbonate ion. Iron is also a constituent of plant material and will be found in surface waters in organic combination. Trouble from iron is always to be expected when there is an excess of organic matter in the material through which the water passes. When ground waters containing iron are first drawn they look clear, but the ferrous iron ( $\text{Fe}^{++}$ ) in solution is soon oxidized to ferric iron ( $\text{Fe}^{+++}$ ). The ferric ion is then precipitated as red flocculent ferric hydrate.

**REMOVAL OF IRON.** There are a number of methods for removing iron from water. The one most commonly used is aeration to oxidize the iron to the ferric state, followed by filtration. Zeolite will also remove iron. A special zeolite regenerated with sodium permanganate is often employed. Lime alone, or lime and chlorine, followed by filtration have been successfully used in a few instances.

Manganese also occurs in ground and surface waters, usually along with iron. It also precipitates on exposure of the water to air. The total content of iron and manganese in potable waters should not be over 0.3 part per million. Manganese is removed by the same methods as those used for iron but with somewhat greater difficulty.

**IRON PIPES.** Nearly all waters attack iron pipes, corroding them and forming tubercles on the inner surface. This is objectionable because it reduces the carrying capacity of the pipe and also influences the quality of the water. The process is continuous, though slow. Many years may elapse before the tubercle reaches the height of an inch. Tuberculation may be prevented by applying certain chemical treatments to the water, or by thoroughly coating the inside of the pipes with specially prepared bitumastic compounds. Cement-lined pipes are also not subject to tuberculation. When the process of tuberculation has advanced far it may be corrected by cleaning the pipe with special scraping tools. These are driven by the water pressure through the pipes. Their whirling blades scrape off the tubercles. Scraped pipes may be relined in place in order to preserve their capacity.

Hot water systems containing iron pipes or tanks are particularly likely to accumulate large quantities of iron, and thus deliver red water, which is objectionable in laundering.

**Lead and Other Heavy Metals.** The presence of lead in water may be discovered by chemical tests; where lead piping or service connections are used in the water system, these tests should be made frequently since dangerous amounts of lead go unnoticed because they have no effect on the appearance or taste of the water. Lead is a cumulative poison.

The sample of water used for a test for lead should be the *first portion* (a pint or less) drawn after the water has stood at least one hour in the pipes. Often the sample examined will not represent the daily maximum.

With the decreased use of lead piping, poisoning from this source is becoming

less frequent. The 1946 Drinking Water Standards of the U. S. Public Health Service state that the presence of more than 0.1 part per million of lead shall constitute ground for rejection of a supply. The question of lead poisoning and its relation to water is discussed in Chapter 40. The standards also limit copper to 3.0 parts per million and zinc to 15.0 parts per million. Arsenic, selenium and hexavalent chromium are limited to 0.05 part per million. The limits prescribed are based on present knowledge of the toxicity of these metals.

**Organic Matter and Nitrogen.** Organic matter in water originates from both plant and animal sources and appears in a great variety of compounds, most of them too complex or too small in quantity to allow of direct determination. There is only one direct determination of organic constituents which is ordinarily made. That is the "loss on ignition" of total solids, which gives the weight of volatile and combustible organic constituents. Ignition is subject to the error of recording unavoidable loss of some mineral compounds. Nevertheless, a fair measure is obtained of the total weight of organic substances as indicated by the loss of combustible material.

**THE NITROGEN CYCLE.** Organic matter in soil or in water undergoes a complex cycle of decomposition and resynthesis in which all types of living organisms have part. The carbon, hydrogen, oxygen, nitrogen, sulfur, and other elements making up organic compounds appear in specific combinations at each stage of this cycle. Figures 37-1 and 37-2 illustrate the nature of the cyclic changes for carbon, nitrogen and sulphur in the decomposition and resynthesis of organic matter; the diagrams are specifically related to organic matter of sewage, but would hold without substantial change for any other forms of organic matter. The course of the cycle is dictated in part by whether or not a sufficient supply of oxygen is present; under anaerobic conditions (absence of oxygen) the end products of decomposition are unoxidized compounds such as ammonia and sulfides, whereas under aerobic conditions, the end products are highly oxidized compounds such as nitrates and sulfates.

The cyclic changes of nitrogen are of particular interest with respect to the elimination of pollution in water by natural forces. Nitrogen exists in living organisms primarily in the form of proteins, which are large and complex molecules in which nitrogen, sulfur, and phosphorus are linked to carbon-hydrogen chains. As soon as the organism dies, the proteins are attacked by saprophytic bacteria, which break them down to smaller fragments. The steps in the decomposition are numerous, passing through peptides (smaller protein-like molecules) and amino acids or amines, to ammonia, the final product of this phase of decomposition. The process is mainly one of hydrolysis. A large variety of bacteria, both aerobic and anaerobic, can carry out this stage of the cycle. The *Bacillus* group is an example of the strictly aerobic types; the *Coli-aerogenes*, *Pseudomonas*, and *Proteus* groups can function under either condition; the *Clostridia* require strictly anaerobic conditions. The result is a decrease in organic nitrogen, and an increase in ammonia ( $\text{NH}_3$ ). In the absence of oxygen, ammonia is the final product, and the organisms using the decomposed material for food must be able to assimilate nitrogen in the form of ammonia, an ability possessed by few organisms except the bacteria.

In the presence of oxygen, the ammonia undergoes further changes; these are



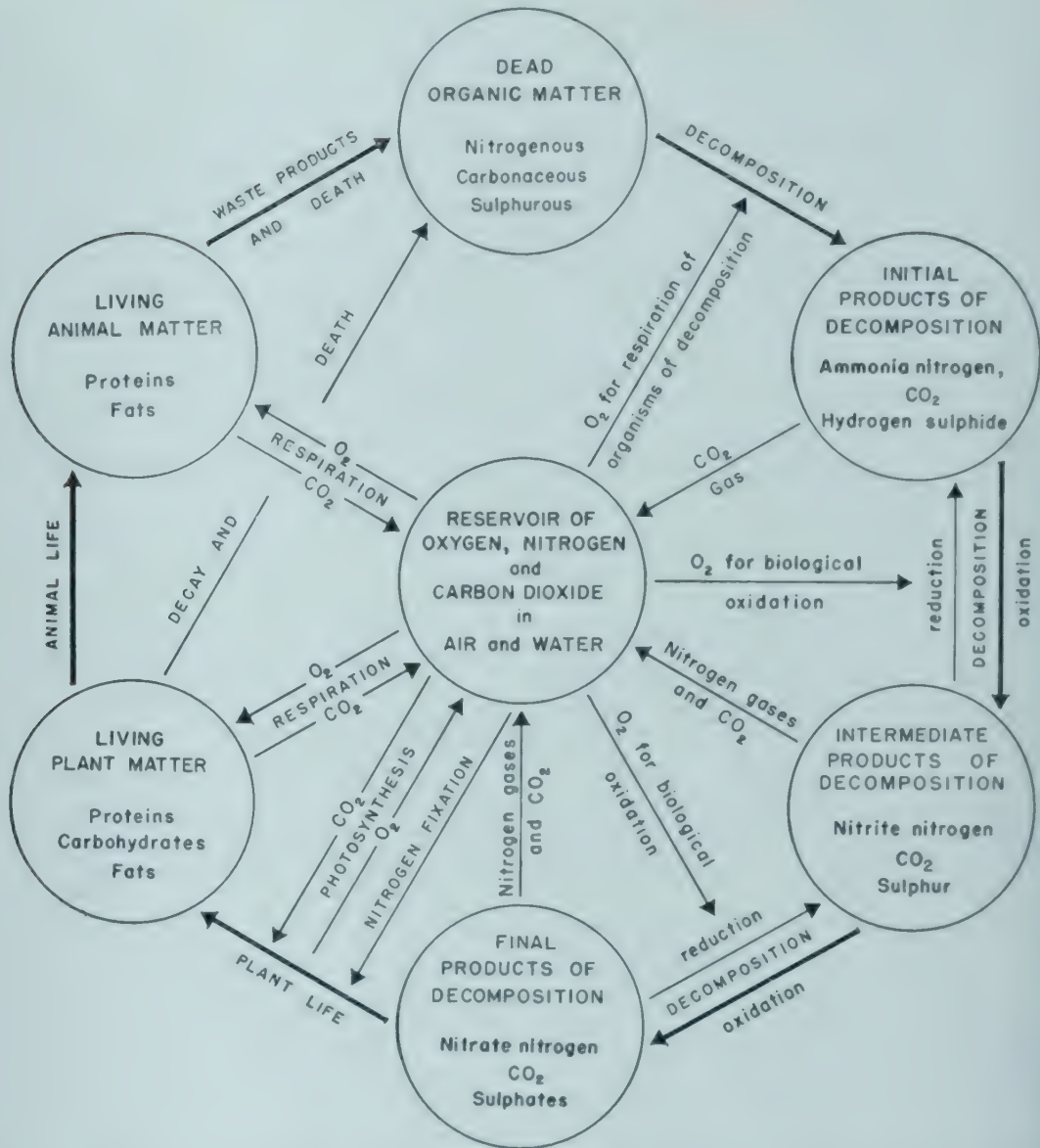


Fig. 37-1. The cycle of nitrogen, carbon and sulphur in its relation to the aerobic decomposition of sewage.

induced by specific organisms, and are reactions of oxidation. The first stage of oxidation, from ammonia ( $\text{NH}_3$ ) to nitrite ( $\text{NO}_2$ ) is carried on by two groups of organisms, *Nitrosomonas* and *Nitrosococcus*. They are so-called autotrophic bacteria, meaning that they derive their energy from the oxidation of an inorganic compound (in this case ammonia) rather than from the oxidation of organic matter. They are strictly aerobic and grow best in media containing but little organic matter; the material which forms the bacterial cell is directly synthesized from carbon dioxide, water, and other mineral compounds.

The second stage of oxidation is from nitrite to nitrate ( $\text{NO}_3$ ). This represents the highest stage of oxidation of nitrogen, and signifies the final "mineralization" of the organic nitrogen. The reaction is carried on by *Nitrobacter*, another aerobic autotrophic organism, which derives its energy solely from this particular oxidation reaction.

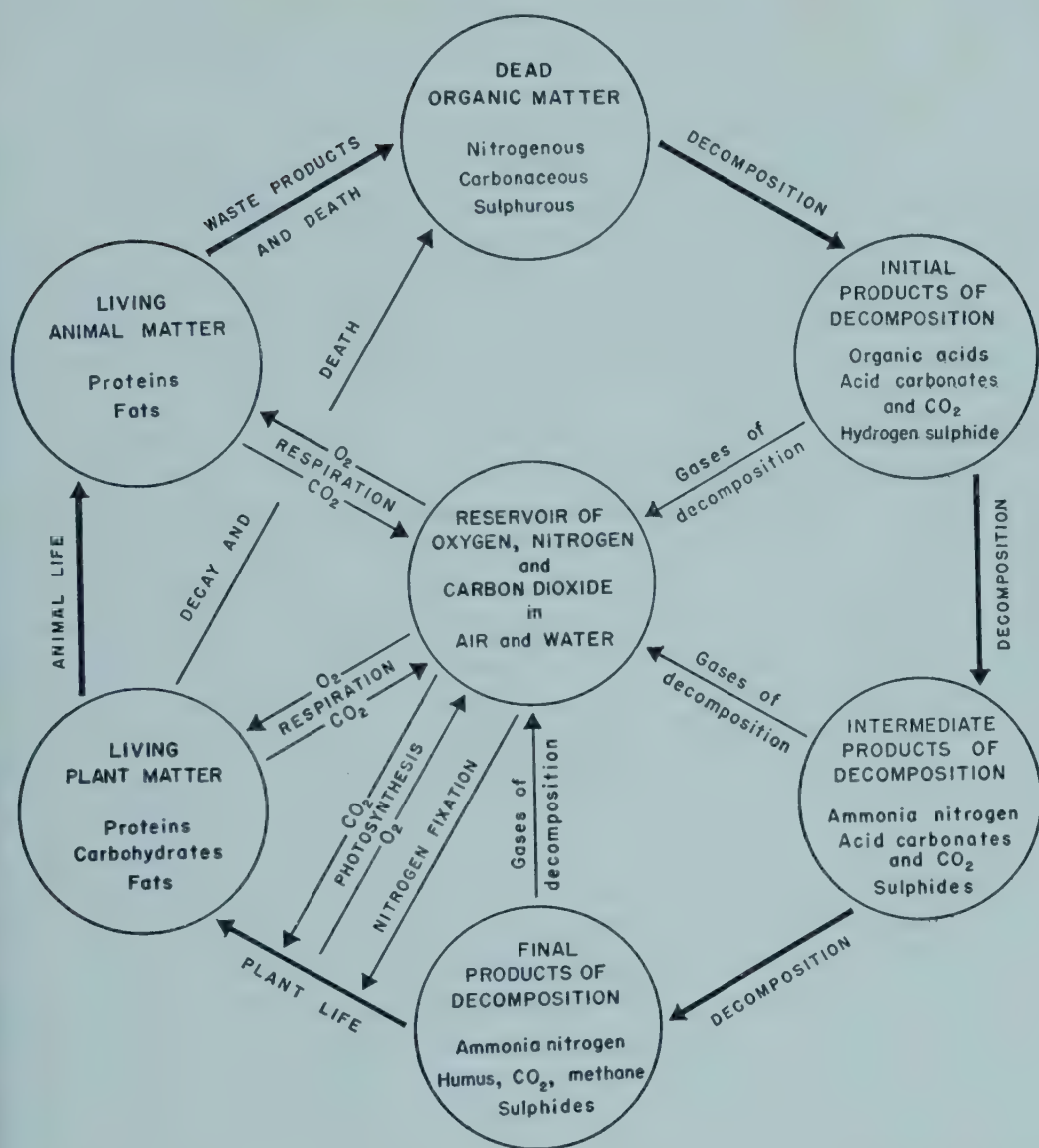


fig. 37-2. The cycle of nitrogen, carbon and sulphur in its relation to the anaerobic decomposition of sewage.

The nitrates form the principal source of nitrogen for algae and plants; the nitrates are taken in by these organisms and utilized to build plant proteins. Plant proteins are in turn utilized by animals to build animal protein. When either plant or animal dies, the cycle of decomposition begins anew.

Certain side reactions may modify the main cyclic process, or temporarily reverse it. For example, if water containing nitrates or nitrites loses its oxygen, some of the saprophytic organisms are able to continue to oxidize organic matter by extracting the oxygen from the nitrites and nitrates, thereby reversing the cycle and returning the nitrogen to the form of ammonia. This is the basis for the use of sodium nitrate in polluted waters for the temporary alleviation of nuisance conditions. A few bacteria can, in the absence of oxygen, convert nitrates to nitrogen gas, which then leaves the cycle by escaping to the atmosphere. On the other hand, an important group of soil bacteria are able to "fix" nitrogen—that is, to extract



it from the atmosphere and assimilate it into protein. Ultimately this assimilated nitrogen becomes available to plants. In water, nitrogen fixation, although it may sometimes occur, is of minor significance.

It is evident from this discussion that much information about the sanitary history and present state of a water can be derived from quantitative determinations of the various forms of nitrogen present. As self-purification progresses, the nitrogen is successively converted from the organic form to ammonia nitrogen, then to nitrite and finally to nitrate. While this process is going on, the pathogenic organisms contained in the polluting material are dying off, and the putrescible organic matter is being eliminated. The relationships between the various forms of nitrogen serve as a useful index of how far the self-purification has proceeded, when properly interpreted in the light of previous experience. Before the modern bacteriological indices of pollution were developed, sanitary chemists were forced to rely too heavily on the nitrogen determinations for this purpose, and unjustified or erroneous conclusions were sometimes drawn from them. For this reason, there has been a tendency to undervalue the usefulness of the nitrogen determinations. However, the increasing interest in stream-pollution studies is returning these determinations to their proper position of importance in the sanitary analysis.

**TOTAL ORGANIC NITROGEN.** All protein matter contains nitrogen, whether it be of plant or animal origin. The organic matter in water comes from both these kingdoms and the protein exists in both living and inert substance. It is present especially in suspended and colloidal particles. The total organic nitrogen may be determined by the Kjeldahl method, and it may be divided by filtration of a sample before analysis into suspended organic nitrogen and dissolved and colloidal organic nitrogen. The former includes that from microscopic organisms, except the bacteria, and organic debris of every sort; the latter, that from extracted and dissociated material. The organic nitrogen determination does not differentiate between plant and animal nitrogen, but high values generally point to animal pollution because of the higher nitrogen content of animal tissue. High values also indicate fresh pollution—that is, that time enough has not elapsed for bacterial digestion of organic matter and oxidation of the nitrogen to more stable forms.

**ALBUMINOID NITROGEN.** A simpler and quicker procedure than the Kjeldahl method is the determination of the "albuminoid nitrogen," or "albuminoid ammonia." In this method only that portion of the nitrogen is oxidized which is not held in stable combination. The yield is ammonia. The albumins fall into this category, hence the term "albuminoid nitrogen." The method consists in distilling a sample of water with strong alkaline permanganate and Nesslerizing the distillate for ammonia. The result is expressed in terms of nitrogen.

The figure obtained is approximately one-half the total organic nitrogen which exists in ground waters or surface waters which have little pollution. In sewage and waste-polluted waters the albuminoid figure is variable and usually constitutes more than half the total nitrogen because nitrogenous matter of animal origin contains not only more nitrogen, but more nitrogen in the form of easily decomposable compounds, such as the albumins.

Like the Kjeldahl method this one also fails to distinguish between plant and animal nitrogen. Ordinarily, high albuminoid nitrogen values are due to a large number of microscopic organisms or to sewage pollution. The determination

therefore, provides a fair index of the organic pollution in water. The organic matter itself is not dangerous to health, but is undesirable because it offers food for bacterial growth, defiles the water, and produces disagreeable tastes and odors.

No arbitrary standard can be set as to the maximum amount of albuminoid nitrogen a good water may contain. It is not uncommon to find as high as 0.1 part per million in surface waters of acceptable quality, but collateral evidence should show this amount to be principally of plant rather than animal origin. Ground waters of good quality contain less than this amount; in most cases practically none.

**AMMONIA NITROGEN.** Ammonia nitrogen is often spoken of as "free ammonia" because it can be driven off or freed by boiling. The amount of free ammonia is determined by distilling a 500-ml. sample and Nesslerizing the first 200 ml. of the distillate in 50-ml. portions. Nessler's solution contains mercuric chloride and potassium iodide and gives a brown color in the presence of ammonia, due to the formation of a complex mercury-ammonia-iodine compound. The amount of ammonia found is expressed in terms of nitrogen.

Ammonia nitrogen exists in water in its free state and in the form of ammonium ion. The sources of ammonia in water are varied; usually it comes from the decomposition of organic matter, as a result of bacterial action. Ammonia is not the last stage in the mineralization of organic matter (see nitrogen cycle, page 1173) for, with the lapse of time, ammonia is oxidized by bacterial action to unstable nitrites and finally to stable nitrates. Both the time and the processes necessary to effect nitrification bring about destruction of organic pollution and substantial elimination of pathogenic bacteria.

Ammonia nitrogen is also formed during the process of bacterial denitrification, by which nitrates and nitrites are reduced to ammonia. This action takes place near the surface of the soil to a limited extent. In natural waters this source is not significant unless anaerobic conditions exist. Denitrification also takes place at times in ground waters when nitrates are reduced by the action of ferrous salts. The water of some deep wells contains several parts per million of ammonia nitrogen derived in this way.

The ammonia itself found in drinking water is harmless; its significance lies in the fact that it indicates the presence of decomposing organic pollutorial matter which may be infected. High ammonia values signify recent pollution, that is, within a period of time which has not allowed oxidation.

Not all the free ammonia in water originates from organic matter. Rain water takes free ammonia from the atmosphere, more especially above industrial communities. The presence of ammonia in clean and properly stored rain water has little significance. It denotes pollution of the atmosphere with gases.

**NITRITES.** Nitrites never accumulate to any extent in water because they are soon oxidized to nitrates, the final and stable form of mineralization of organic nitrogen. Nitrites represent a transitional stage of decomposition between ammonia and nitrates. Nitrites, when high, suggest bacterial activity. Nitrites are an index, just as the presence of coliform organisms is an index. Their significance varies with the amount, the source, and the relation to other constituents in the water.

Nitrites have less significance when ammonia nitrogen is low and nitrate nitrogen is high, and greater significance when the reverse is the case. A low ammonia content is evidence of little protein material in a state of decomposition.



In unpolluted ground waters nitrogen will not be found as nitrites, except as there may have been reduction of nitrates by ferrous compounds or other reducing agents. When this happens the amount of nitrites is likely to be high and can be disregarded in the light of other tests which register an absence of pollution.

Concerning the amount of nitrites in water it must be remembered that the colorimetric test for nitrites with sulphanilic acid and  $\alpha$ -naphthylamine acetate is one of the delicate tests in chemistry. With this method we are able to detect quantities of nitrogen as small as one part per billion. When, therefore, a water analyst reports a trace of nitrites it means an exceedingly minute quantity.

Nitrites are poisonous compounds, but the minute amounts found in water can scarcely have a pharmacological effect.

**NITRATES.** Nitrates represent the final stage in the mineralization or oxidation of nitrogen originally present in organic compounds. Nitrates are used as food by plants for the upbuilding of new protein, which important step completes the cycle that nitrogen passes through in its continuous circulation in nature (see **nitrogen cycle**, page 1173).

The detection of nitrates in water depends upon the yellowish color produced by the reaction of the nitrate ion with phenoldisulphonic acid and sodium hydroxide. The amount can be determined by comparison with standard solutions.

In the same sense that nitrites may suggest danger, nitrates may indicate safety. Nitrates, being the final stage of protein decomposition, are a sign that decomposition of polluting protein is complete, provided that organic nitrogen and nitrites are absent. The presence of nitrates is not of itself evidence of safe quality in drinking water, for nitrates must be interpreted in the light of the bacteriologic findings and other contributing data. When the nitrates are high but other forms of nitrogen are absent or present only in traces, it means that the water was polluted, but purification has taken place. Under these circumstances nitrates tell the chemical story of the past history of the water.

Nearly all surface waters of safe quality contain nitrogen as nitrates in amounts varying from 0.1 to 1.0 part per million. There is considerable seasonal fluctuation due to use of nitrates for food by algae and other forms of plant life. Nitrates in surface waters come largely from the soil where there is constant mineralization of nitrogenous organic matter. When surface water has been heavily polluted at some distant point with either soil washings or liquid wastes the nitrate content may be several parts per million of nitrogen.

Shallow ground waters often show large amounts of nitrates, from one to several parts per million. This may be due to oxidation of soil nitrogen or of wastes thrown upon or in the ground. If the latter, there is a considerable element of danger shown by the nitrate content, unless organic matter and other forms of nitrogen are practically absent.

High nitrates in deep ground waters usually have their origin in underground mineral deposits and are without sanitary significance. Young (1911) has shown that the ground waters of Kansas sometimes contain large amounts of nitrates—as much as 500 parts per million. The medicinal dose of potassium nitrate is 0.3 gm. Less than a liter of such water would, therefore, contain sufficient nitrates to produce effects such as irritation of the mucous membrane of the stomach, and also diuresis, with irritation of the mucous membrane of the bladder. Much lower

amounts of nitrate, perhaps as little as 10 to 20 p.p.m., cause cyanosis in infants (see Chapter 40).

**OXYGEN CONSUMED.** One of the oldest tests for organic matter in water is the oxygen-consumed test which measures the amount of potassium permanganate consumed by this organic matter in the presence of acid. Unstable organic compounds are oxidized by the permanganate, which in turn is reduced and decolorized. The amount of permanganate used up may be expressed in terms of oxygen, and this value is taken as the "oxygen consumed" by the oxidizable matter present.

There are several facts which operate to impair the usefulness of this test. In the first place, the oxygen values will vary with the temperature and time of digestion. It is, therefore, important to record the conditions of the test, or results will not be comparable with the results of others. Again, the determination tells nothing as to the source or kind of organic matter. It was thought at one time that carbonaceous organic matter was oxidized in this way in contrast to nitrogenous material by the albuminoid nitrogen test, and that the results accordingly registered pollution by plant material. This is only partially true, and the test in no way can be used to distinguish between organic matter of plant and animal origin. Neither does it record the oxygen necessary to stabilize all the organic matter present, for the test is not carried that far; nor does it give much idea of the ease with which the organic material is oxidized—that is, how unstable it may be. However, there is a great need for a rapid chemical test for unstable organic matter, and considerable effort is being made to improve this test, or to develop others. The use of potassium dichromate has been investigated and shows possibilities.

Oxygen-consumed values when used alone are not of great significance but give corroborative information in interpreting the results of other determinations, such as color, loss on ignition, organic nitrogen and albuminoid nitrogen. They are also useful in comparing periodical fluctuations in oxidizable matter.

Good ground waters show practically no oxygen consumed, for they contain very little organic matter. In surface waters free from waste pollution the oxygen consumed will usually vary as the color, ranging from 1.0 to 10 parts per million.

**Dissolved Oxygen and Biochemical Oxygen Demand.** Water in contact with the air becomes saturated with oxygen. Being held in solution, as a gas in a liquid, the oxygen is termed "dissolved oxygen." This quantity has no relation to "oxygen consumed." The actual amount of gas present will depend upon the partial pressure of oxygen in the atmosphere, upon the barometric pressure, and upon the temperature of the water. In most cases temperature is the controlling factor, for the amount of oxygen dissolved varies greatly with temperature. Thus, distilled water at 0° C and 760 mm. pressure holds, when saturated, 14.6 parts per million of oxygen; at 20° C it holds 9.2 parts.

There are many processes which go on in water that influence the dissolved oxygen content. Clean surface waters are ordinarily saturated with dissolved oxygen, but in the presence of rapidly growing plant life, particularly algae, supersaturation often occurs due to liberation of oxygen by the plant cells. At the same time there is a reduction of the carbon dioxide content which is used as food for plant growth. The relation of dissolved gases to microscopic growth in water is close and important.

When water is polluted with any oxidizable material, such as the extracted



matter from dead vegetation, sewage, or other wastes, the oxygen content will be diminished, but may be replenished by absorption from the atmosphere if the pollution is not heavy and decomposition not too rapid. When the demand of bacterial and related activity for oxygen exceeds the rate at which oxygen can be dissolved from the air, the concentration of dissolved oxygen in the water will fall and, as it approaches zero, putrefaction arises due to anaerobic bacterial processes. This results in the production of compounds which possess obnoxious physical properties. In surface waters receiving sewage or industrial wastes this condition may produce a nuisance.

Dissolved oxygen is a most important determination in the study of pollution. The amount of oxygen found is an indication of the load which is being put upon natural processes of purification. The amount found in the water of a flowing stream at different points, for instance, furnishes valuable information as to the rapidity with which self-purification is taking place below a given point of pollution.

The amount of oxygen required for the aerobic bacterial oxidation of the organic matter present in a sample can be measured by diluting the sample with water containing a buffer and certain necessary minerals, and seeding the mixture with an active bacterial culture. The mixture is incubated at 20° C in a closed bottle containing no air space for a specified number of days, customarily five. The amount of dissolved oxygen used up by bacterial action during the incubation period is determined by measuring the dissolved oxygen content of the mixture before and after the incubation. This figure, when multiplied by the reciprocal of the dilution, gives the biochemical oxygen demand of the sample, expressed as p.p.m. of oxygen. The biochemical oxygen demand may also be determined in manometric or volumetric incubation vessels; in these, the oxygen is taken from a closed gas space above the liquid. The amount of oxygen used is measured either by the decrease in pressure or the decrease in volume of the gas; any carbon dioxide produced in the course of the oxidation must necessarily be removed.

The biochemical oxygen demand test is of the greatest importance in stream-pollution studies and in the evaluation of sewage treatment. Despite certain shortcomings, it is the only method available for approximating the actual demand for oxygen which will be exerted during the bacterial decomposition of organic matter in water. The balance between the rate and amount of biochemical oxygen demand, the available dissolved oxygen, and the rate at which oxygen can be absorbed from the atmosphere, is what determines whether a polluted body of water becomes a nuisance inhabited only by anaerobic bacteria, or remains in a reasonably acceptable state, with a normal biological population.

Oxygen concentration has an important relation to fish life. Most fish will live when the oxygen content is as low as 3 to 4 parts per million. Below this point suffocation takes place, the critical value depending upon the variety of fish.

Nearly all lakes and impounded water supplies show a decrease in oxygen content with increasing depth. Frequently none is found near the bottom during the summer months. This results from the thermal stratification of the water which creates a zone of stagnation at the bottom. Due to its greater density the water here does not reach the surface for aeration, and decomposition at the same time is more active than at the surface, due to concentration of organic impurities from natural sedimentation. Water in the zone of stagnation is impregnated with foul

products of decomposition and should be avoided for general domestic use unless it is suitably treated before consumption.

Ground waters are usually partially or wholly depleted in oxygen content, due to percolation of the surface water through the soil where oxidation of organic matter is in progress.

**Fluorides and Iodides.** The fluoride content of drinking water has considerable importance in sanitary analysis because of its effect on the tooth structure of infants and growing children who use the supply. Fluorides in excess of one p.p.m. cause structural defect in the teeth known as mottled enamel; on the other hand, very low fluoride concentrations in water appear to promote susceptibility to dental caries. Therefore, it may be necessary in some water supplies to consider either the removal or addition of fluoride. The subject is discussed in more detail in Chapter 40. Analysis of waters for fluoride content becomes necessary both to determine the desirability of addition or removal, and to control such treatment once it is instituted. Fluoride is determined by making use of the decolorization of a zirconiumalizarin lake; the degree of decolorization, which is proportional to the amount of fluoride present, is determined by comparison with standards. If interfering ions, such as chloride, sulphate, or iron, are present, the sample must be distilled before making the test.

The iodide content of drinking water also has possible sanitary significance. In regions where iodides are low or absent in the soil and water, the incidence of goiter is believed to increase. This is true particularly in regions which were once covered by glaciers. At one time, sodium iodide was added to a few water supplies to overcome this defect. The practice ceased when it was found to be more effective and economical to supply the needed iodine in the form of iodized salt. However, it may sometimes be advisable to investigate the iodine content of a water supply to determine whether a deficiency exists. A concentration of less than 5 parts per million as iodide is considered to indicate a deficiency.

### MICROSCOPIC EXAMINATION

The term "microscopic organisms" as used by the water analyst includes all organisms, whether plant or animal, free floating (plankton) or attached that are visible or barely visible to the naked eye, other than bacteria. The bacteria are apart, inasmuch as their significance and the method of studying them are different from all other micro-organisms.

The microscopic organisms comprise the diatoms, green algae, blue-green algae, fungi, protozoa, rotifers, crustaceans, numerous small worms, insect larvae, and other organisms minute in size. Fragments of organic matter, broken-down organisms, zoogaea, etc., should be termed amorphous matter and measured, but oxide of iron and mineral matter in general are excluded.

The chief object of the microscopic examination of water is the determination of the presence or absence of those micro-organisms which produce objectionable tastes and odors. The determination is also of value as an index of pollution or as evidence to the identity of the water. A full discussion of the subject of microscopic organisms will be found in *Microscopy of Drinking Water* (Whipple, 1927).

The sanitary quality of water cannot be definitely shown from a microscopic examination. Surface waters are usually rich in microscopic life, while ground



waters are comparatively free. However, as soon as ground waters stand in pipes or are exposed to the light, microscopic organisms may develop.

**The Sedgwick-Rafter Method.** This is the standard method for counting the number of microscopic organisms in water and measuring their volume. It consists in collecting the microscopic particles suspended in a known quantity of water, and estimating their volume in a cell of known depth under the microscope. The microscopic particles are concentrated upon sand by filtration. An alternative method is the use of a specially designed high-speed centrifuge. Full details of the procedure may be found in *Standard Methods for Examination of Water and Sewage*. The results are expressed as standard units of organisms per ml. of water, a standard unit being a cube 20 microns on a side.

**Significance of the Examination.** The microscopic examination of water is of value in supplementing the chemical and bacterial analyses. It may explain the cause of odors and tastes in a water; it may explain certain chemical determinations, as albuminoid ammonia, dissolved oxygen, oxygen consumed, carbon dioxide, etc.; it may indicate sewage contamination; it may suggest the state of self-purification of a polluted water; it may identify the source of the water.

Several of the microscopic organisms, when present in sufficient quantities, give rise to objectionable odors and tastes, either when in a vegetative state or upon decomposition. The natural odors of organisms are due to oils analogous to the essential oils. In general, the diatoms have an aromatic odor, increasing to that of a geranium leaf, and even to an intensity that is fishy. The Cyanophyceae, or blue-green algae, have a grassy or musty odor. The Chlorophyceae or green algae ordinarily have grassy odors that are not particularly undesirable, although some of the motile forms give rise to faintly fishy odors. The ciliated protozoa have, in general, no odor. The Chrysophyceae (yellow-green), notably *Synura*, *Uroglenopsis* and *Dinobryon*, and the Dinophyceae or dinoflagellates, especially *Ceratium* and *Peridinium*, give rise to particularly objectionable oily and fishy odors. Of the other microscopic organisms, such as the rotifera and crustacea, no forms have been recorded as giving rise to objectionable odors.

Certain members of the blue-green algae, for example, *Anabaena*, *Microcystis*, and *Aphanizomenon* have caused the death of cattle and other domestic animals when present in water in sufficient quantities to form heavy scums. Such water would not ordinarily be consumed by humans, but a few instances of illness due to smaller concentrations of the algae have been reported. These algae have been shown to secrete a toxin, as yet unidentified because of the difficulty of isolating it from other organic compounds present in the algae. A much greater menace to humans is the dinoflagellate, *Gonyaulax catenella*, a sea water organism. During the warm months these organisms are sometimes ingested in great numbers by mussels, and occasionally by other shellfish. Consumption of these shellfish by humans produces a violent and often fatal poisoning, due to the presence of a toxic alkaloid in the *Gonyaulax*. Outbreaks of mussel poisoning have been reported from Nova Scotia and from the West Coast. The outbreaks are often associated with a concentration of *Gonyaulax* sufficient to give a red tinge to the sea water.

The plankton population is a good indicator of sewage pollution and self-purification. Being sensitive to its environment, the population changes in character as purification proceeds. There is usually a sequence of forms following the B

of pollution and these forms are potent factors in purification. The protozoa utilize complex organic matter and the bacteria as food. Their growth is followed by that of the algae, which use up the  $\text{CO}_2$  of decomposition processes, as light conditions improve. Then come the rotifera and crustacea, the former feeding largely upon minute algae, and the crustacea making use of certain protozoa and decayed fragments of plant and animal matter. Thus, some of the microscopic organisms play the role of scavengers, others are predatory in their food habits.

Besides these animal and plant forms there may be present also sponges, mosses, yeasts, and molds, the significance of which is varied and dependent upon local conditions.

### BACTERIOLOGICAL EXAMINATION

Practically all natural waters contain bacteria. This is true of rain water, ground water, and the waters of lakes, rivers, and oceans. The number and variety of the bacteria vary greatly in different places and under different conditions. The bacteria are washed into the water from the air, from the soil, and from almost every conceivable object. The intestinal contents of animals pollute waters with enormous numbers of micro-organisms, but it is the infection with certain species from man that makes water most dangerous when consumed by other men.

A final judgment of the potability of a water should never be based upon the bacteriological examination alone, but should be combined with a sanitary survey and other laboratory tests. A sanitary survey may discover possibilities of danger, even though the sample examined contains few bacteria and no members of the coliform group. On the other hand, a water may contain large numbers and miscellaneous kinds of harmless bacteria and a sanitary survey will confirm absence of human pollution. The chemical and microscopic examinations assist in the interpretation of bacteriologic findings.

**Number of Bacteria in Water.** Incubation of samples of water of appropriate volume in solid nutrient media contained in Petri dishes permits the growth of visible bacterial colonies which can be counted at the end of the incubation period. The medium ordinarily used is tryptone glucose agar, and the plates are incubated either at  $20^\circ \text{C} \pm 0.5^\circ$  for  $48 \pm 3$  hours, or at  $35^\circ \text{C} \pm 0.5^\circ$  for  $24 \pm 2$  hours. The results are expressed as numbers of bacteria per ml.; this involves the assumption that each colony developed from a single organism. Formerly the results were termed "total bacterial counts," but it has long been recognized that only a fraction of the bacteria present in the sample are counted, and that no single incubation medium can be prepared that will yield even an approximation of the true total number of bacteria in the water. For example, the autotrophic bacteria, including nitrifying organisms so important in stream purification, cannot be grown on organic media, and therefore do not appear in the "total count." The latest edition of *Standard Methods of Water Analysis* simply designates the results secured by the incubation procedure as "standard plate count at  $20^\circ \text{C}$ ," or "standard plate count at  $35^\circ \text{C}$ ," and expressly avoids the term "total count."

The standard plate counts, then, include only that portion of the bacteria in the water that are capable of growing in the standard medium at the temperature of incubation. These are predominantly the common saprophytic bacteria: they



do not necessarily have any sanitary significance. However, in conjunction with other information, and particularly when past records exist, the standard plate counts may serve as useful indices of changing sanitary conditions. For example, if a well water previously showing low counts, should suddenly show a count of several hundred per ml., contamination of the well would be suspected. In general, uncontaminated well waters can be expected to yield plate counts not greater than 100 to 200 per ml. In surface waters, the plate counts are generally much higher than they are in ground waters, and vary roughly with the degree of pollution, including in the term any kind of organic addition from sewage to the washings from completely uncontaminated soils. Unfortunately, a dangerous fecal contamination may not increase the plate count of a surface water as much as a completely harmless influx of washings from a virgin soil.

At one time, specific standards were set up for maximum permissible numbers of bacteria as determined by plate counts in waters to be used for various purposes. Because of the uncertainty in the interpretation of such counts, these standards have been largely abandoned. The use and significance of plate counts is further discussed in the section on bacteriological limits of pollution.

**Kinds of Bacteria in Water.** There are available bacteriological technics which make it possible to isolate and determine a large number of the species of bacteria which may be present in water. Many, although not all, of the water-borne pathogens, particularly those causing cholera, typhoid, and dysentery, can be thus isolated and enumerated. Such investigations are, however, rarely made except in special research studies. The test for the presence of a single group of organisms—the coliform group—is used almost exclusively as a bacteriological index of the degree of pollution of the water.

There are a number of reasons why this should be so. For one thing, the isolation of the coliform group is comparatively easy, whereas the isolation of many of the other significant species of bacteria, especially the pathogens, is cumbersome and difficult. Again, when one considers the purpose of a sanitary analysis, it is evident that what is sought is evidence of possible avenues of infection rather than the actual presence of infective organisms at the time of analysis. The coliform group is present in large numbers in the feces of all animals that are known to be possible carriers of water-borne disease; the average person excretes from 200 billion to 400 billion of these organisms per day, depending on the season of the year. It is therefore evident that any fecal pollution of water results in the presence of organisms of the coliform group. It is even possible to estimate the degree of pollution of a water with a fair accuracy by determining the numbers of coliform organisms present, and by combining such estimates with knowledge of the incidence of a given water-borne disease, say typhoid, in a community, to estimate the probability that the disease will be acquired by an individual drinking the water.

The coliform group, like the water-borne pathogens, is not adapted to live and multiply indefinitely in water. However, its resistance to the forces of natural purification has been shown to be somewhat greater than that of the common water-borne pathogens. Consequently, the assumption is justified that if coliform organisms have been eliminated from water by long-continued storage, the pathogens have also disappeared. The same thing is, for the most part, true of the comparative resistance of the two groups to the methods used in water purification.

particularly the procedures used in disinfection. Such evidence as we have indicates that the resistance of the organisms of typhoid and dysentery to chlorination is certainly not greater than, and is very probably less than, that of the coliform group. Unfortunately, the same cannot be said of the cysts of the organism causing amebic dysentery, which are much more resistant to disinfecting agents than are the coliform organisms.

It can, therefore, be concluded that the determination of coliform organisms furnishes a highly satisfactory index of water quality with respect to the presence or absence of dangerous pollution. Like all other tests, it has its defects; the principal one is the inclusion in the group of a certain number of species which are of nonfecal origin, and therefore of debatable significance with respect to the safety of a water supply. Consequently, there has been considerable effort to find an organism which will serve as a more precise and exclusive index of fecal pollution. Although some possibilities—for example, the fecal streptococci—have recently been suggested, there is as yet no visible tendency to substitute any of them for the coliform group, except in special investigations.

**The Coliform Group.** The coliform group includes all aerobic and facultative anaerobic Gram-negative, nonspore-forming bacilli which ferment lactose with gas formation and grow aerobically on standard solid media. The standard tests for members of this group are the *presumptive*, the *confirmed* and the *completed* test. For complete information on these tests, Standard Methods of Water Analysis should be consulted.

**Types of Coliform Organisms.** The group includes both fecal, or intestinal, organisms and nonfecal organisms. Typical of the first group is *Escherichia coli* and of the second *Aerobacter aerogenes*. The former has its normal habitat in mammals and birds, and even in some cold-blooded animals, and, therefore, is properly called fecal. The nonfecal type is found in soil, on fruit, leaves, grain and in many other places in nature. The significance of the two types is not very distinct, since feces of man and other animals also contain a number of nonfecal types. Because of the difficulty of differentiation, the doubtful significance of the results, and the general advance of sanitary standards, most sanitary authorities, at least in this country, are of the opinion that acceptable drinking water should be substantially free from all coliform organisms, fecal or nonfecal. In England and on the European continent, differentiation into fecal and nonfecal types is still regarded as important, and the presence of nonfecal coliforms is permitted to a considerable extent (Prescott and others, 1946).

**Presumptive Test for Coli-Aerogenes Group.** Presumptive or incomplete tests for members of the coli-aerogenes group afford useful information as to their possible presence. Except for waters in the process of purification, such tests are usually confirmed or completed, as indicated below. The presumptive test is made by adding to each of five fermentation tubes containing suitable amounts of lactose lauryl sulphate tryptose broth, 10-ml. or 100-ml., portions of water. For non-polluted waters, smaller portions should also be tested, such as 10 ml., 1 ml., and 0.1 ml., so as to obtain a quantity small enough to give a negative test. The fermentation tubes are incubated for 48 hours at  $35^{\circ} \pm 0.5$ . Formation of gas within  $48 \pm 3$  hours constitutes a *Positive Presumptive Test*. Absence of gas formation in this period constitutes a negative test.



It may be presumed in the absence of fermentation that coliform organisms are absent, and also that fermentation with gas production suggests their presence. Both these conclusions may be misleading. Grossly polluted waters containing many such bacilli may be slow in fermenting sugars with the production of gas on account of the preponderance of other more active species. On the other hand, organisms other than members of this group often found in water ferment sugars with gas production. It is, therefore, necessary to isolate the suspected organism in pure culture and pass it through the confirmatory tests before it is labeled a member of the coli-aerogenes group.

**Confirmed Test.** This is made from tubes showing gas formation in the presumptive test. Streak plates of either Endo or eosin-methylene-blue agar should be made from the tubes containing the smallest and next smallest amounts of water that gave gas formation. The plates should be incubated for 24 hours at 35° C. If colonies typical of members of the coli-aerogenes group form, it is a *confirmed test*. If no typical colonies form, incubation is prolonged to 48 hours, when two or more colonies considered most likely to be members of this group are treated as in the completed test. As a substitute for the plates, inoculation into brilliant-green lactose bile may be used; formation of gas within 48 hours at 35° C constitutes a *confirmed test*.

**Completed Test.** From the Endo or eosin-methylene-blue agar plates of the partially confirmed test, one or more typical colonies should be transferred to an agar slant and to a lactose broth fermentation tube, which should be incubated at 35° C for 24 hours and 48 hours, respectively. If brilliant-green lactose bile has been used as the confirmatory medium, the Endo or eosin-methylene-blue agar plates may be streaked either from the original lactose tubes or the brilliant-green tubes.

Demonstration of Gram-negative, nonspore-forming bacilli on the agar slant and formation of gas in the lactose broth constitute a *positive completed test*. Failure in either of these steps constitutes a negative test.

A positive completed test gives assurance of the presence of a member of the coli-aerogenes group in the original sample of water. Any evidence that may be desired of the fecal or nonfecal nature of the organism must be obtained by applying a number of differentiating tests, as described in Standard Methods of Water Analysis.

To express the density of coliform organisms in the water, use is made of the Most Probable Number, which is determined from the results of incubating several portions of water; for example, 5 portions each of 10 ml., 1 ml., and 0.1 ml. Tables are given in Standard Methods of Water Analysis for the evaluation of Most Probable Numbers. The Most Probable Number of coliform organisms is that number per 100 ml. of water that would be most likely to give the results observed in the series of fermentation tubes. The usual practice in the analysis of potable water is to incubate five 10-ml. portions and a single 1-ml. portion. The most probable numbers of coliform organisms for the various possible combinations of positive tubes are given in the table below.

Increasing the number of portions incubated, and using portions of three sizes such as 10 ml., 1 ml., and 0.1 ml., increases the precision of the Most Probable Number.

Number of Positive Tubes		Most Probable Number per 100 ml. of Water
10 ml.	1 ml.	
0	1	2.0
1	0	2.2
1	1	4.4
2	0	5.0
2	1	7.6
3	0	8.9
3	1	12.0
4	0	15.0
4	1	21.0
5	0	39.0
5	1	Indeterminate

**Significance of the Coli-Aerogenes Group.** The absence of members of the coli-aerogenes group in water proves its safety so far as bacteriology can prove it. It is fair to assume that typhoid bacilli, dysentery bacilli, and other intestinal parasites would not be likely to be present in a water in the absence of these bacilli. It is possible to conceive that a water might be polluted with urine alone containing typhoid bacilli, but no colon bacilli, but such an event is highly improbable.

The presence of a member of the coli-aerogenes group, then, is a danger signal; its absence, a sign of probable safety. Final judgment, however, should not be made on the presence or absence of these bacteria alone. The findings should be interpreted in the light of other information obtained in the laboratory and in the field.

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## INTERPRETATION OF SANITARY WATER ANALYSIS

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The interpretation of a sanitary water analysis is much more difficult than the analysis itself. Single or occasional analyses are of limited value. A single water analysis may even be misleading, especially of surface waters. A river water may require repeated examinations extending over long periods of time and correlated with conditions of rainfall, stream flow, wind, temperature, sewage pollution, and other factors in order to secure helpful information. Ground waters should certainly be examined both during wet and dry seasons.

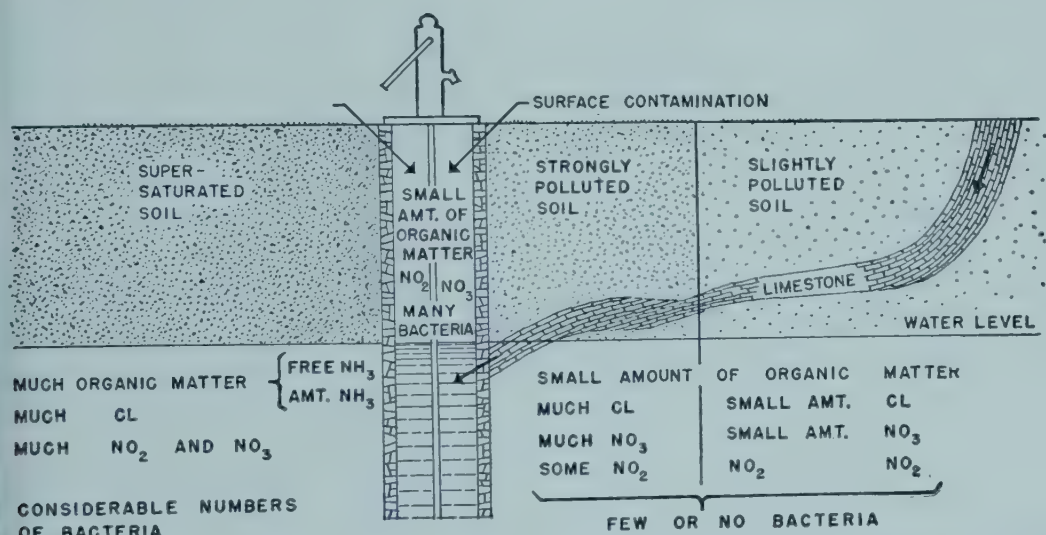
The ordinary routine chemical and bacterial examination of water affords but meager information, especially when only one analysis has been made. Fortunately, the inferences drawn from a sanitary water analysis are on the safe side, and many good waters are condemned; in fact, it is very difficult for an unsafe water to pass a complete sanitary analysis.

The information furnished by an analysis relates only to present conditions and is not a guarantee of future safety. A surface water or a ground water may today be exceptionally free from chemical impurities and practically sterile bacteriologically, whereas tomorrow it may contain organisms causing typhoid, dysentery, cholera, or other water-borne infection; these may come from sources that would at once be evident from a sanitary survey of the watershed. Therefore, a sanitary survey of the catchment area is frequently of much greater practical importance than all the information furnished by the laboratory. Neither a chemical nor a bacteriological analysis is needed to tell us that the water from a creek with an overhanging privy a short distance above will some day carry infection; or that the water from a shallow well in limestone or coarse gravel near a leaking cesspool must be a source of danger. A sanitary survey should discover the sources of contamination, the kinds of pollution, and the degree, often with greater precision than combined chemical or bacteriological tests. No sanitary analysis of a water can, therefore, be considered complete unless it includes an examination of the watershed and a study of the geology and topography of the catchment area.

With the progressive improvement of bacteriological methods, chemical indices of contamination have lost some of their former importance, but valuable inferences may be drawn from the determinations of organic matter, free ammonia, nitrates, chlorides and, in some cases, hardness and alkalinity. The various tests for organic matter are difficult of interpretation, unless they registered marked differences from values known to be normal for the source of the sample, or unless they are used in conjunction with other tests. An experienced observer can learn much

about the condition of the water by use of the odor test. Odors of vegetable decay, such as "peaty" and "vegetable," indicate organic matter from dead vegetation or the presence of a few microscopic organisms. Grassy, aromatic and fishy odors point to heavier growths of more objectionable plankton. Musty, moldy and disagreeable odors like those accompanying putrefactive processes indicate the possible presence of sewage or other organic wastes which may carry contamination. Tarry, oily, and chemical odors serve to detect certain industrial wastes. Albuminoid nitrogen should be small in amount in good ground waters and also in surface waters which have very little vegetable matter, as shown by the color test. High albuminoid nitrogen is due to vegetable coloring matter, algae and similar organisms, or to nitrogenous waste, which usually means sewage. If much sewage is present, there will be a noticeable increase in turbidity.

All the nitrogen tests, if taken together, give evidence as to sanitary conditions. High ammonia nitrogen figures are suspicious in any sample of water, except in occasional deep wells, where the ammonia is derived from mineral sources. Good ground waters contain only traces. Surface waters not subject to contamination will



g. 38-1. Diagram illustrating the character of the ground water in relation to soil pollution, assist in the interpretation of a sanitary analysis. (See also nitrogen cycle, page 1173.)

ve little ammonia except in the presence of algal growths which are in a state of integration. Ammonia indicates proximity to a source of pollution. Nitrites, too, e a danger signal, for the reason that they show incomplete oxidation of nitrogen-s waste. Nitrites in the presence of nitrates are also an indication of incomplete rification. Nitrates (in the absence of nitrites) indicate complete mineralization organic matter and, therefore, are evidence of distant or past pollution. Chlorides ove the normal for the region can be attributed to sewage or other wastes. The rce may be near or distant, for the chlorides are stable.

Hardness and alkalinity are usually derived from mineral sources, but in soft ter regions sewage adds appreciable quantities of the hardness constituents. rdness and alkalinity may, therefore, furnish contributing evidence of sewage llution although, like chlorides, they afford no measure of the proximity of llution.



Waters that vary in composition from time to time without evident cause must be regarded as questionable. This applies particularly to ground waters. Surface waters vary greatly as the result of freshets, etc., but a ground water should show no sudden variations.

**Bacteriological Limits of Pollution.** Although it is possible to define limits of pollution more closely in terms of bacterial content than in terms of chemical constituents, the standards once set for the standard plate counts of bacteria growing at 20° C and 37° C have been abandoned. The plate counts are still considered to furnish useful information in conjunction with other analyses, particularly with respect to stream pollution studies, control of purification plants, and the like. General ranges for unpolluted waters may also be stated; for example, unpolluted surface waters will seldom yield more than 300 to 400 organisms at 20° C, and about one-sixth as many at 35° C, whereas deep ground waters will usually show less than 200 at 20° C, and less than one-tenth of this number at 35° C. Shallow-ground waters may often contain large numbers of bacteria at 20° C without pollution, although the number of organisms at 35° C will remain low in the absence of pollution. Very high counts at 35° C are usually an index of sewage pollution in water. However, the interpretation of the results obtained from plate counts has proved to be difficult for a given water in the absence of an extensive previous record, and the importance of the plate counts in the sanitary analysis of water has greatly diminished in recent years. Many laboratories now make them only in connection with special studies where many data are to be accumulated, as, for example, in studies of the effect of chlorination on the disposal of sewage in a stream, or in an evaluation of the performance of a water purification plant.

On the other hand, determination of the number of coliform organisms has become the principal criterion of the sanitary quality of water. The standards of the U. S. Public Health Service are based primarily on this determination, as the sole measure of potential infectiveness. In the most recent revision of the standards (1946), the following criteria are adopted for drinking waters:

(1) Of all the standard 10-ml. portions examined per month, not more than 10 per cent shall show the presence of organisms of the coliform group, as indicated either by the *completed* or the *confirmed* test.

(2) Occasionally three out of five of the 10-ml. portions constituting a single standard sample may show the presence of coliform organisms, provided that this does not occur in consecutive samples, or in more than 5 per cent of the standard samples examined per month, or in more than one standard sample when less than 20 standard samples are examined per month.

The number of samples required to be examined per month is determined by the population served by the water supply, and is specified in the reference given. It ranges from one per month for a supply serving less than 2,500 people, to 500 per month for a supply serving 5,000,000.

That portion of the Public Health Service standard that requires that not over 10 per cent of all portions be positive is, in effect, a requirement that the average most probable number of coliforms per 100 ml. shall be 1.05 or less. However, if the actual analysis of individual samples, each consisting of five 10-ml. portions, one positive tube signifies a most probable number of 2.2 per 100 ml. For the

reason, some laboratories now use five 100-ml. portions as a standard sample, instead of the 10-ml. portions. Comparable standards for the larger portions as set up by the Service are as follows:

(1) Of all standard 100-ml. portions examined per month, not more than 60 per cent shall show the presence of coliform organisms.

(2) Occasionally all five of the 100-ml. portions constituting a single standard sample may show the presence of the coliform group, provided that this does not occur in consecutive samples, or in more than 20 per cent of the standard samples, or in more than one standard sample when less than five standard samples are examined per month.

The use of 100-ml. portions allows a sharper differentiation of waters as to most probable number of coliform organisms at and near the allowable level. The most probable number corresponding to requirement (1) is 0.51 per 100 ml. (three out of five tubes positive), and the next step above it (four out of five positive) corresponds to a most probable number of 0.92.

For waters to be used for purposes other than drinking, but where potential infection is still of some importance—for example, bathing waters and those used for shellfish culture—there is as yet no general agreement on standards. For public swimming pools the American Public Health Association has set up the following specifications: a plate count of less than 200 bacteria per ml. at 35° C and absence of coliforms in five 10-ml. portions in at least 85 per cent of all samples. This is substantially equivalent to the drinking water standards. For outdoor bathing places, the standards applied by various states run all the way from 50 to 3,000 coliform organisms per 100 ml., with the trend toward the lower values. The State of Connecticut, for example, classifies outdoor bathing waters as follows:

	Coliform Organisms per 100 ml.
Class A, Good . . . . .	0-50
Class B, Doubtful . . . . .	51-500
Class C, Poor . . . . .	501-1,000
Class D, Very poor . . . . .	over 1,000

The figures for bathing places are in terms of the "coli index"; the most probable number is 2.3 times this value.

For waters used for the growing of shellfish, the U. S. Public Health Service recommended the following standards in 1945:

	Coliform Organisms. Most Probable Number per 100 ml.
Approved areas . . . . .	Not over 70
Restricted areas . . . . .	70 to 700
Grossly polluted areas . . . . .	over 700

Shellfish grown in approved areas may be marketed without treatment, and those in restricted areas after proper chlorination. Grossly polluted areas are closed.

## EXAMPLES OF ANALYSES AND INTERPRETATIONS

Several sample analyses of waters, ranging from good to highly polluted, are presented as illustrations of the principles previously outlined.



## ANALYSIS No. 1: Gross Pollution

	Parts per Million
Free ammonia . . . . .	0.214
Albuminoid ammonia . . . . .	0.810
Nitrogen as nitrites . . . . .	0.005
Nitrogen as nitrates . . . . .	21.0
Chlorine as chlorides . . . . .	47.0
Total residue . . . . .	412.0
Volatile residue . . . . .	279.0
Fixed residue . . . . .	133.0
Bacteria per ml. upon gelatin at 20° C . . . . .	65,000
Bacteria per ml. upon agar at 37° C . . . . .	120,000

Fermentation in lactose broth in 0.001 ml. Coliform bacilli confirmed in 0.01 ml.

This represents a grossly polluted water and should unhesitatingly be condemned, no matter what its source. All of the chemical indices of pollution, the ammonias, nitrites, and nitrates, are high; chlorides are also high, although this would depend on the normal for the region. The bacterial counts are large, and the number of coliform organisms present is excessive.

## ANALYSIS No. 2: Stony Brook Reservoir in the Winter

	Parts per Million
Free ammonia . . . . .	0.050
Albuminoid ammonia . . . . .	0.197
Nitrogen as nitrites . . . . .	0.001
Nitrogen as nitrates . . . . .	0.37
Chlorine as chlorides . . . . .	6.0
Color . . . . .	37
Odor . . . . .	distinct vegetable, faint aromatic
Microscopic organisms . . . . .	59 standard units per ml.
Bacteria per ml. at 20° C . . . . .	500
Bacteria per ml. at 37° C . . . . .	80

Coliform organisms, present in 1 ml.

This water is from an impounding reservoir that delivers raw water to the Cambridge, Mass., purification works. A fairly well populated catchment area, on which there is control of wastes, contributes to it. At times analysis would indicate the water to be fit for consumption without purification. The purpose of this analysis is to show that the supply is subject to deterioration at certain seasons and hence requires purification for year-around protection of its consumers.

The ammonias are moderately high and reflect the entrance of organic matter into the supply. They are not due to microscopic organisms, which are few in number. The nitrates are high enough to indicate wash from fertilized fields, or remote sewage pollution. Chlorides exceed normal for the region by 2 to 3 parts per million, indicating the presence of human or animal wastes.

Color is too high and odor too conspicuous for the water to be attractive without purification. The bacterial content is considerably higher than usually obtained in clean surface waters, and the density of the coliform group is indicated to be higher than that shown by a safe water. The water is of questionable sanitary quality, as judged by both the chemical and bacteriological analyses.

ANALYSIS No. 3: Boston Tap Water Typical in 1915 (not averaged results)

	Parts per Million
Free ammonia . . . . .	0.010
Albuminoid ammonia . . . . .	0.114
Nitrogen as nitrites . . . . .	0.000
Nitrogen as nitrates . . . . .	0.02
Chlorine as chlorides . . . . .	2.7
Total residue . . . . .	27.0
Volatile residue . . . . .	10.0
Fixed residue . . . . .	17.0
Hardness . . . . .	13.0

Bacteria per ml. upon gelatin at 20° C . . . . . 77

Coliform organisms, absent in 50 ml.

This is a surface water, collected in impounded reservoirs and stored about 10 days before it reaches the consumer. The watershed is fairly well protected. The chemical analysis shows little organic pollution; the ammonias are moderate in amount, nitrites absent; nitrates low; chlorides normal; bacteria indicate nothing suspicious. The water is of good sanitary quality, judged by chemical and bacterial analysis. For such a water chlorination is the only treatment necessary to ensure safety.

ANALYSIS No. 4: A Suspicious Shallow Well Water

	Parts per Million
Free ammonia . . . . .	0.018
Albuminoid ammonia . . . . .	0.020
Nitrogen as nitrites . . . . .	0.007
Nitrogen as nitrates . . . . .	1.5
Chlorine as chlorides . . . . .	19.3
Total residue . . . . .	106.0
Volatile residue . . . . .	37.0
Fixed residue . . . . .	69.0
Hardness . . . . .	33.8

Bacteria per ml. upon gelatin at 20° C . . . . . 60

Bacteria per ml. upon agar at 37° C . . . . . 45

No fermentation in lactose broth in 10-ml. portions.

This water came from a driven well at Wenham, Massachusetts. Upon inspection it was found that the well was 400 feet from a stable, 200 feet from a cesspool, and 250 feet from the house.

The first thing that strikes our attention in this analysis is the high amount of chlorides. This, however, lacks precise sanitary significance, as it is close to the normal for the ground waters of this neighborhood. The hardness of the water is due to the mineral deposits in the surrounding soil through which the water percolates. The organic matter as represented by the ammonias is low. The nitrates are high and indicate that the water has dissolved this end product of the oxidation of organic matter in its passage through the soil and perhaps in seepage from the cesspool. The fairly high quantity of nitrites indicates that all the organic matter has not been consumed and that the mineralization is not complete. The small number of bacteria present shows that the filtering action of this soil through which



the water passes is effective in keeping out sewage contamination either from the surface or from the cesspool. This conclusion is strengthened by the absence of fermenting organisms.

This particular sample of well water shows nothing injurious to health, and, if subsequent analyses are equally satisfactory, the water may be used without fear for drinking purposes. It is plain, however, that this well needs watching, for it is evident that the soil is already surcharged with organic matter, some of which appears in the water, and a further loading of the soil or a break in the cesspool might readily contaminate the water.

## ANALYSIS No. 5: Pollution of a Well

	Parts per Million
Free ammonia . . . . .	0.022
Albuminoid ammonia . . . . .	0.035
Nitrogen as nitrites . . . . .	0.007
Nitrogen as nitrates . . . . .	1.0
Chlorine as chlorides . . . . .	19.0
Total residue . . . . .	356.0
Volatile residue . . . . .	151.0
Fixed residue . . . . .	205.0

(Residue charred with disagreeable odor upon ignition.)

Bacteria per ml. upon gelatin at 20° C . . . . .	9
Bacteria per ml. upon agar at 37° C . . . . .	275

Fermentation in lactose broth in 0.1 ml.  
Coliforms confirmed in 1 ml.

This was a shallow well (28 feet deep) in Washington, D. C. The water depth was four feet. There was a sewer 60 feet from the well and a privy within a block. The pump was old and the cover to the well was rotten at the base.

Although this water contains only a moderate amount of nitrogenous organic matter, as indicated by the ammonias, every other factor indicates serious contamination. The nitrates and nitrites are high; the chlorides are excessive. It is important to notice that this water has only nine bacteria per ml. when judged by the colonies that grow upon gelatin at 20° C. Nevertheless, it contains 275 bacteria per ml. growing at 37° C, and coliform organisms in 1 ml. It is probable that most of the contamination in this case came from the sewer. The water should obviously not be used for domestic purposes.

## ANALYSIS No. 6: Well Water, Surface Pollution

	Parts per Million
Free ammonia . . . . .	0.007
Albuminoid ammonia . . . . .	0.018
Nitrogen as nitrites . . . . .	0.0005
Nitrogen as nitrates . . . . .	2.5
Chlorine as chlorides . . . . .	14.0
Total residue . . . . .	62.0
Volatile residue . . . . .	32.0
Fixed residue . . . . .	30.0

(Residue charred with disagreeable odor upon ignition.)

Bacteria per ml. upon gelatin at 20° C . . . . .	820
Bacteria per ml. upon agar at 37° C . . . . .	640

Fermentation in lactose broth in 1 ml.  
Coliforms confirmed in 10 ml.

This water came from a shallow well (18 feet deep) in Washington, D. C. The water stood three feet from the bottom. The high nitrates and chlorides in this case represent past pollution. The small amount of organic matter with a trace of nitrites plus the number and character of the bacteria indicate surface pollution. This view is strengthened by the fact that repeated examinations of the water from this well showed marked variations in the number of bacteria. Upon inspection the pump and covering to the well were found in very bad condition and leaky; surface drainage was toward the well.

#### ANALYSIS NO. 7: Illustrating Remote Pollution

	Parts per Million
Free ammonia . . . . .	0.006
Albuminoid ammonia . . . . .	0.011
Nitrogen as nitrites . . . . .	trace
Nitrogen as nitrates . . . . .	20.0
Chlorine as chlorides . . . . .	89.0
Total residue . . . . .	430.0
Volatile residue . . . . .	113.0
Fixed residue . . . . .	317.0

(No charring upon ignition.)

Bacteria per ml. upon gelatin at 20° C . . . . .	92
Bacteria per ml. upon agar at 37° C . . . . .	16

No fermentation in lactose broth in 10 ml.

This was a ground water from a shallow well in Washington, D. C. The well is 29 feet deep and the water stood four feet from the bottom. The top was well protected; waste water drained to a sewer nearby. There were two privy vaults within two blocks of the well.

The analysis shows high chlorides and nitrates, otherwise nothing suspicious. This means remote pollution. The organic matter has been completely mineralized and the bacteria held back by the soil. The high result for volatile matter was due to volatilization of mineral constituents.

#### ANALYSIS NO. 8: High Free Ammonia; Deep Well

	Parts per Million
Free ammonia . . . . .	0.170
Albuminoid ammonia . . . . .	0.000
Nitrogen as nitrites . . . . .	trace
Nitrogen as nitrates . . . . .	0.0
Chlorine as chlorides . . . . .	3.1
Total residue . . . . .	115.0
Volatile residue . . . . .	45.0
Fixed residue . . . . .	70.0

No bacteria per ml. upon gelatin at 20° C.  
No bacteria per ml. upon agar at 37° C.  
No fermentation in lactose broth.



This water was from a driven well 96 feet deep in Washington, D. C.; water stood 81 feet from the bottom. Good platform and drain, and pump in first-class condition.

It is exceptionally pure, both chemically and bacteriologically, except for the large amount of free ammonia. It is not too uncommon to find water from deep wells to be high in free ammonia, and it is assumed that this comes from a chemical reduction of the nitrogenous mineral matter by ferrous compounds. Another possibility may be the release of ammonia from natural zeolites.

ANALYSIS NO. 9: Rain Water Stored and Polluted

	Parts per Million
Free ammonia . . . . .	1.050
Albuminoid ammonia . . . . .	0.175
Chlorine as chlorides . . . . .	2.0
Nitrogen as nitrites . . . . .	distinct trace
Nitrogen as nitrates . . . . .	0.0
Oxygen consumed . . . . .	2.25
Total residue . . . . .	20.0

Bacteria per ml. upon gelatin at 20° C 625  
No coliforms.

This is rain water from a dirty cistern. In appearance the water was clear and good. The analysis shows that the water is polluted with organic matter as evidenced

ANALYSIS NO. 10: Chemical and Bacteriological Changes in Potomac River Water as the Result of Storage and Filtration

(The figures are averages of weekly samples over a period of a year.)

	Dalecarlia Inlet: Raw Water Entering Storage Reservoir	Dalecarlia Outlet: Raw Water After About 2 Days' Storage	Georgetown Reservoir: Second Storage Reservoir (Water Remains Here About 2 Days)	Washington Reservoir: Third Storage Basin (Water Remains Here About 3 Days)	Filtered Water from Filtered Water Reservoir
Turbidity	86.0	30.0	29.0	18.0	1.0
Free ammonia	0.006	0.008	0.005	0.004	0.002
Albuminoid ammonia	0.107	0.106	0.101	0.077	0.027
Nitrogen as nitrites	0.0027	0.0023	0.0027	0.0027	0.0001
Nitrogen as nitrates	0.19	0.18	0.18	0.17	0.19
Chlorine as chlorides	2.9	3.4	2.9	2.7	2.8
Hardness	93.2	95.5	93.4	94.0	94.9
Bacteria per ml. upon gelatin at 20° C	14,300.0	13,900.0	10,900.0	6,800.0	141.0
Per cent samples show- ing coliform group in 10 ml.	45.5	45.3	37.9	23.6	1.1
Per cent samples show- ing coliform group in 1 ml.	26.9	24.0	19.8	10.4	0.8

From Whipple, G. C., Microscopy of Drinking Water. Courtesy of John Wiley & Sons, Inc., New York

° Water not disinfected.

CASES				ODOR				
DESCRIPTION OF SAMPLE				Dissolved Oxygen		Carbon Dioxide	Cold	Hot
Sample Number	Time of Collection		Temp- ature	Parts per Million	Per cent of Saturation			
	Date 1926	Hour						
A	Sept. 1	1 p.m.	65°F	9.48	100	1.5	1v	1v
B	"	2 "	68°	8.80	96	2.0	2v	3v
C	"	3 "	66°	7.96	85	5.0	3v+2M	4M
D	"	4 "	72°	10.12	115	0.0	2M+3g	4g
E	"	4 "	50°	0	0	25.0	4H <sub>2</sub> S	3d+3H <sub>2</sub> S
F	"	5 "	65°	9.48	100	2.0	1v	1v
G	"	6 "	71°	3.55	40	10.0	2M+3d	3M+3d
H	"	5:30 p.m.	75°	0.85	10	25.0	4d	5d

ORGANIC MATTER																	
LIVING ORGANISMS																	
ALGAE etc., Standard Units per cc																	
Color	Loss on Ignition			Nitrogen as Albuminoid Ammonia		Total Organic Nitrogen	BACTERIA			Total Organisms	Principal Groups						
	Total	Sus- pended	Dis- solved	Total	Sus- pended		Dis- solved	Tests for B. Coll.									
								0.1 cc	0.1 cc		1.0 cc	10 cc					
A	10			.035			2.1	50	10	0	0	50	40				
B	15			.085			3.0	350	150	0	+	300	175	60	30		
C	30			.210			16.5	390	50	0	0	550	200		175	100	
D	21			.320			11.0	150	20	0	0	3200	300	2600			
E	46			.155			18.0	650	70	0	0	400	100			225	
F	7			.020			1.8	35	4	0	0	25	20				
G	40			.750			14.0	9000	7500	0	+	1000*		200	500	150	
H	300	185	205	5.000			62.0	2.0M	1.5M	+	+	150	25		70	50	

MINERAL AND ORGANIC MATTER										MINERAL MATTER															
Solids										Nitrogen as															
Turbidity	Total			Sus- pended			Dis- solved			Alka- linity	Incrus- tants	Iron	Magne- sium	H.I.C. pH	Free Ammonia			Nitrites			Nitrates				
	Total	Sus- pended	Dis- solved	Total	Sus- pended	Dis- solved	.006	.025	.040						.020	.180	.004	.2200	14.000	.001	.002	.001	.002	.010	.000
A	2	30		20			2.3	12.0	10.0	2.0	0.1			6.7											0.20
B	4	42		27			2.6	16.0	11.0	5.0	0.2			6.8											0.75
C	3	55		25			2.4	10.0	9.0	1.0	0.4			6.6											0.33
D	8	46		25			2.5	13.0	10.0*	3.0	0.2			7.4											0.10
E	15	79		33			2.6	15.0	11.0	4.0	2.5			6.0											0.00
F	1	49		42			2.3	27.0	20.0	7.0	0.1			6.9											0.15
G	25	110		70			12.0	42.0	32.0	10.0	0.5			6.7											0.20
H	220	750	250	360	65	295	55.0	80.0	95.0	0	1.5			7.0											0.10

\*Includes 150 standard units of rotifer.

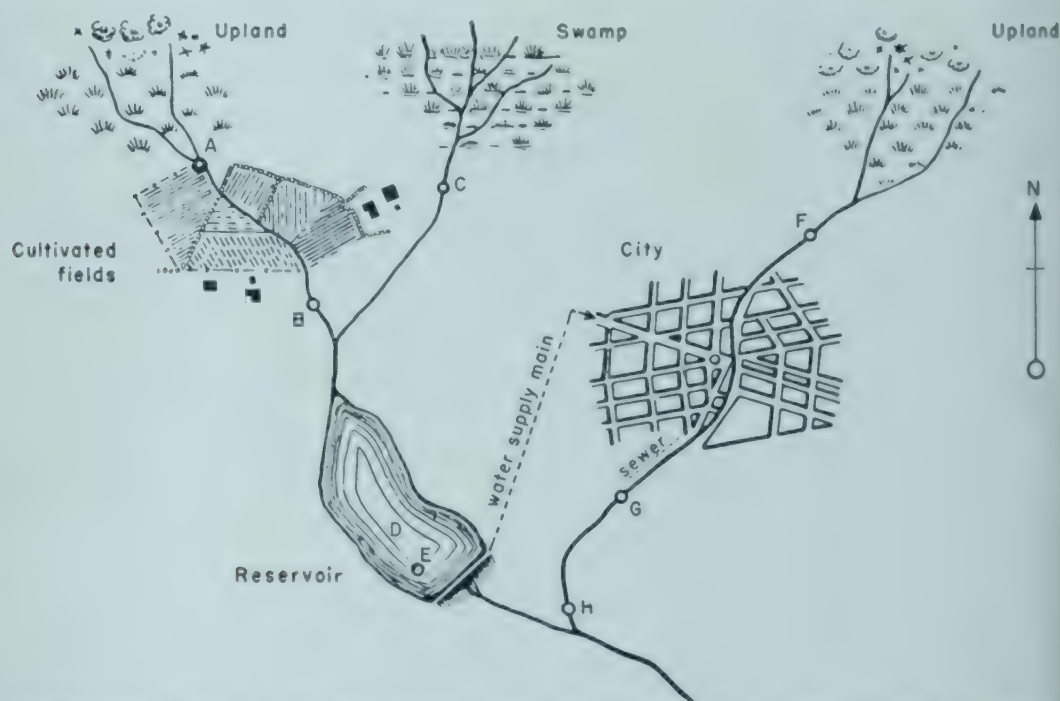
Results of chemical analysis are expressed in "Parts per Million" i.e., Milligrams per Liter.



by the albuminoid ammonia, oxygen consumed, and plate count. The bacteriological results indicate absence of fecal pollution. The water is undesirable, but not dangerous, as far as the possibility of infection is concerned.

Analysis No. 10 is a good illustration of the bacteriological and chemical character of a river water, and illustrates the changes that occur during short storage (about seven days) and after filtration through a slow sand filter.

It will be seen from this table that the turbidity is markedly reduced by sedimentation during storage and by filtration. There is a gradual diminution in the amount of free ammonia and a more marked diminution in the amount of albuminoid ammonia. The nitrites show a marked decrease after filtration, indicating the rapid completion of the oxidation of the organic matter in the filter. The nitrates show a tendency to increase in amount, which would be expected as the nitrites diminish. It is evident that storage and filtration have little effect upon the chloride content of the water.



Adapted from Whipple, G. C., *Microscopy of Drinking Water*, New York, John Wiley & Sons, Inc., 1927.

Fig. 38-2. Location of sampling stations.

The number of bacteria decreases as the result of storage, but the most marked decrease occurs as the result of filtration. Likewise, the effect of the few days storage materially affects the number of coli-aerogenes organisms, and there is a marked diminution in their number following filtration.

The analyses of surface waters, shown in Analysis No. 11, with diagram (Fig. 38-2) of the locations from which samples were obtained, will repay careful study.

#### TEXT REFERENCE

U. S. PUBLIC HEALTH SERVICE. Public Health Service drinking water standards, 1946. *Public Health Rep.*, 61:371, 1946.

## THE PURIFICATION OF WATER

EDWARD W. MOORE, M.A.

The purification of water—that is, the production of hygienically safe and aesthetically pleasing water from a polluted or contaminated source—makes use of a number of physical and chemical processes for the removal of undesirable constituents. Some of these processes, such as aeration, sedimentation, and filtration through sand, are also active in natural purification; others have no counterpart in nature—for example, chlorination and adsorption by activated carbon. The art of purifying water on a practical scale consists of combining in proper sequence those processes which are essential to the removal or modification of the undesirable constituents present in the particular water to be treated. The objective is twofold: the removal of disease-producing bacteria and other organisms, and the elimination of substances which may be harmful, unpalatable, or objectionable in appearance, or may interfere with the use of the water for technological purposes.

A list of the principal processes used in water purification, together with the effects they produce on the composition of the water, is given below. Those processes which are active in natural as well as artificial purification are placed first in the list.

## PROCESS

## RESULTS

Aeration . . . . .	Tastes and odors diminished. Iron and manganese made insoluble. Corrosiveness decreased by $\text{CO}_2$ removal, increased by $\text{O}_2$ addition. In natural purification, supplies $\text{O}_2$ for oxidation of organic matter.
Coagulation . . . . .	Turbidity, color, iron, manganese and bacteria brought together into large flocs that settle readily. Natural coagulation by agglomeration of soluble and colloidal material; artificial coagulation by addition of chemicals, e.g., aluminum sulphate.
Sedimentation . . . . .	Turbidity and bacteria reduced. Coagulated substances removed.
Filtration . . . . .	Turbidity, iron, manganese and bacteria removed. Color, tastes and odors reduced. Includes natural filtration through soil.
Softening . . . . .	Hardness removed.
Disinfection (chlorination) . . . . .	Bacteria removed. Odors and tastes possibly increased; decreased by superchlorination and dechlorination, by break-point chlorination, or by chlorine and ammonia treatment.



Adsorption (activated carbon)	(Slower kill of bacteria than straight chlorination.)
Corrosion correction	Odors and tastes prevented and removed.
	Reduction of tendency to dissolve metal from pipes, tanks and other structures and to form tubercles or rust deposits.

No method or combination of methods of purifying water can be considered satisfactory that does not first of all eliminate water-borne diseases. To effect this with certainty generally requires the removal or destruction of all but a few of the original bacterial population. There is perhaps no final reason for permitting a few to remain. They are allowed under present practice because such a degree of purification represents one that appears to eliminate water-borne infection and one that can be accomplished at reasonable cost. At present there is no evidence that the few bacteria left in water after a satisfactory process of purification, such as filtration and disinfection with chlorine, are injurious. Certainly, if injurious influence is exercised, it is too small to be determined by any methods now at our disposal.

If the water is to possess esthetic appeal, any process of purification used must also reduce turbidity, color, odors and tastes to inappreciable amounts. Likewise, purification should produce a water that is economical to use. It should not seriously corrode pipes, boilers and fittings; it should not stain clothes in the laundry; it should not cause excessive waste of soap in the household or in industry; it should not cause heavy incrustations in boilers, nor should it possess any quality that will cause consumers to resort to bottled waters. The standards of quality demanded have tended to rise as rapidly as advances in the art of purification have permitted.

**Nature's Methods.** In nature, water is purified by various methods, the chief of which are: (1) evaporation and condensation, which makes rain water the purest of natural waters; (2) the self-purification of streams, which is a variable and uncertain process; (3) storage in lakes and ponds, which clarifies water and which in time eliminates danger; and (4) the physical, chemical, and biologic action of the soil upon water that filters through into the earth, one of nature's greatest purifying agencies.

**EVAPORATION AND CONDENSATION.** The distilling and condensing process through which all meteoric water passes is one of nature's more reliable purification processes. Enormous quantities of sea water, marsh water, and polluted water of all kinds are thus returned to us suitable for domestic use. The ocean has been compared to a boiler, the sun to a furnace, and the atmosphere to a vast still. The cooler air of the higher atmosphere and colder zones act as a condenser, causing the precipitation of the distilled water as rain.

**SELF-PURIFICATION OF STREAMS.** There can be no denial of the fact that streams become purer during the course of their flow. But this is at best a half-truth based upon chemical data and has in the past too often been used to justify acceptance of unsafe waters. Streams become purer, but not pure. Some dangerous components may remain, particularly disease-producing organisms. All surface supplies, except those from uninhabited catchment areas, are now regarded with

suspicion and are stored, filtered, chlorinated, or otherwise purified before they are used.

It was formerly said that a stream purifies itself in seven miles. Such a generalization is absurd. It is not the distance that controls but the time and opportunity for natural purification to become effective.

The pollution and recovery of several large streams in the United States have been studied and reported upon by various government agencies, principally the U. S. Public Health Service, and the Public Health Departments of various states (Crohurst, 1933; Crohurst and Veldee, 1927; Hoskins and others, 1927; Massachusetts, Merrimac Joint Sewerage Board, 1947; Purdy, 1930; U. S. Ohio River Committee, 1944).

The forces active in natural purification are of three kinds: (1) *physical*, the most important of which are aeration, light and gravity; (2) *chemical*, outstanding among which are oxidation, reduction, and coagulation; and (3) *biological*, principally concerned with the food habits of various micro-organisms that promote purification.

**AERATION.** This force operates by exchange of gases between the atmosphere and the water. Wind action, turbulent flow and waterfalls all promote the influence that aeration plays. Oxygen is absorbed from the atmosphere and the gases of decomposition, such as carbon dioxide, hydrogen sulphide, and methane, are liberated from the water. The rate of oxygen absorption is controlled by various factors, the chief of which is the degree of undersaturation of the water, that is, the ability the water has further to absorb oxygen before becoming saturated.

**LIGHT.** The natural color of water, originating for the most part in swamps, is leached somewhat by the action of light, a contribution to self-purification processes. The greatest contribution of light, however, is its stimulation of the process of photosynthesis in aquatic plant life, as a result of which oxygen is added to the water and  $\text{CO}_2$  is removed. The activity of plant life also leads to the consumption of amino acids and possibly other soluble organic nitrogen compounds. Sunlight also exercises some germicidal power upon all surface waters. The depth of penetration is slight in any natural water containing color and turbidity.

**GRAVITY.** Gravity causes sedimentation of suspended impurities and of colloidal particles that have coagulated into larger masses. Sedimentation is favored in quiet water and in slow moving streams containing organic and inorganic suspended solids. Coagulation and sedimentation likewise remove organic bacterial food from the water. The same principles are used to clarify water with chemical coagulants such as aluminum sulphate.

**OXIDATION.** Organic matter is gradually oxidized and converted to mineral substances. The aerobic bacteria are the principal agents in this oxidation. During the course of flow the complex nitrogenous substances are thus mineralized. Chemical analyses show a rapid decrease in the amount of organic matter and an increase in nitrates, and diminution of nitrites. It was these facts that led chemists to conclude that flowing rivers soon purified themselves. In addition, oxidation is a aid to the precipitation of such dissolved mineral substances as iron and manganese compounds.

**REDUCTION.** Although aerobic processes predominate in most places, anaerobic decomposition proceeds where oxygen is lacking. In zones of heavy pollution and



at the bottom a variety of reactions may go on in the absence of oxygen. Hydrolysis and splitting of organic compounds result in their liquefaction and gasification and prepare the way for subsequent oxidation. The products of such reductive reactions are often objectionable. The agents are anaerobic bacteria.

**BIOLOGICAL FORCES.** All living organisms in the polluted water, from bacteria and plankton, to mollusks, fish, and water weeds, contribute to further the process of natural purification. Physical improvement and stabilization go forward in series of zones, often well marked in streams by a succession of forms of life.

High bacterial numbers are followed by growths of protozoa which are largely bacteria-eaters. Then, as physical improvement of the water permits penetration of light, the green algae make their appearance. They consume  $\text{CO}_2$ , nitrates, nitrites and ammonia, and produce copious amounts of oxygen. The large aquatic plants act similarly to the algae and also utilize the food elements found in bottom deposits.

Following the protozoa and algae, such forms as crustacea and rotifers may become numerous. They consume algae, bacteria and protozoa and some of them ingest quantities of decaying organic detritus. All these biological forces tend to free the water from impurities. In addition, worms, larvae, and mollusks are at work in the water and in the bottom deposits, pushing forward the work of stabilization of raw food substances.

The efficiency of all the agencies that tend to decrease numbers of bacteria improves with prolongation of the period over which they act. Time is essential for the self-purification of water. Pathogenic bacteria tend to die in water because it is an unfavorable environment. They succumb somewhat more quickly in a polluted water than in a clean one because of hostile biological forces. It is probable that bacteriophages, among other things, play a part.

**STORAGE IN LAKES AND PONDS.** The same forces that have been described as potent in the self-purification of streams manifest themselves in the improvement of stored waters, although the zones in which this takes place are not as clearly delimited as in streams. Almost no organisms pathogenic for man multiply in water under natural conditions. In time they die out. Hence a properly stored water is reasonably safe. In addition, the organic matter undergoes decay and is transformed to simple mineral constituents. A stored water will in time free itself not only of harmful parasites, but also of most of its organic pollution. Storage is a natural and economical method of improving the quality of the water. Many large communities rely in part on long continued storage in large reservoirs to provide a safe water. In times of drought, the storage period in such reservoirs may be seriously reduced, and their protective value thus diminished.

**Distilled Water.** The distillation of water effects practically complete removal of chemical impurities, and unless there are gross defects in the equipment or its operation, distilled water is also substantially free from bacteria.

However, the cost of distillation is comparatively high, so that it can only be considered as a means of water purification under special circumstances, particularly when water of excessive salinity is the only kind available. There is great interest in reducing the cost of distillation, so that it can be used to produce adequate water supplies from sea water and excessively salty well waters in regions where fresh water is lacking. The development of the vapor compression still has materially reduced the cost of distillation, but it is still high compared to the cost

of purifying fresh waters by the conventional methods. Distilled water, despite statements to the contrary, is entirely suitable as drinking water as far as physiological effects are concerned. The so-called "flat" taste, often present in distilled water, and ascribed to the absence of air, is more probably due to the concentration of volatile odoriferous substances from the raw water in the distillate. The vapor compression still, which operates at a comparatively low temperature, is less prone to produce water of disagreeable taste than the direct-fired still.

**Boiled Water.** Boiling water for five minutes will destroy any of the organisms of water-borne disease, and a shorter time will suffice for most of them. This applies at sea level only; at higher altitudes the period of boiling should be lengthened. Boiling is an effective disinfection measure which is simple enough to be carried out by the general public, and as such should be always resorted to in an emergency. It does not remove toxic chemicals, unless these are highly volatile substances such as hydrogen sulphide.

**Coagulation and Filtration. SAND FILTERS.** Sand filters consist of basins or containers filled with sand, supported on gravel and stone, and suitably underdrained. The water is passed downward through such a filter. If the rate of filtration is low (usually 5 million gallons per acre per day or less) the filter is called a slow filter; if the rate is high (generally 125 million gallons per acre per day or over) the filter is called a rapid filter.

The water in the slow sand filter passes very deliberately through the layer of sand; the filter chokes by the clogging of the superficial layer of sand, and this type of filter can only be cleaned by removing this surface layer of *Schmutzdecke*,

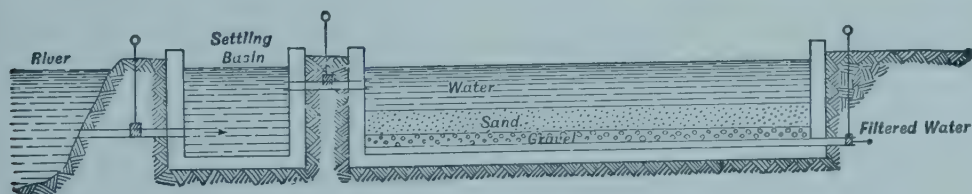


Fig. 39-1. The arrangement of a slow sand filter.

it is called. In rapid sand, or mechanical, filtration the water is first coagulated by chemicals, such as aluminum sulphate, settled, and then passed rapidly through coarser sand. The filter is cleaned by backwashing with water, sometimes with the aid of air or mechanical stirring. Because of the greater efficiency and economy of rapid sand filtration, the slow sand filter is rapidly becoming obsolete.

**Slow Sand Filters.** The slow filtration of water through sand originated as an empiric process, imitating nature's method of purifying water as it slowly passes through the soil. It was used before the chemistry or bacteriology of the process was understood. We know that the spaces between the sand are large when compared with the size of bacteria; nevertheless, about 99 per cent of the bacteria are held in the superficial layers of the sand. Nitrification and oxidation of organic matter also take place. The process is by no means a simple straining. Bacteria and other micro-organisms in the upper layers of the sand grow and form a geluleal mass; each grain of sand becomes coated with a gelatinous and adhesive film. A continuous sticky layer forms upon the surface a carpet-like mass constituting the *Schmutzdecke*, which aids in holding back the bacteria in the water.



Adsorption and absorption by this layer are the major forces in purification of the water passing through it.

A slow sand filter requires an extensive tract of land. The filtering surface is divided into units known as filter beds. In the filters most recently constructed each bed occupies about one acre. Each bed must be an independent unit, so that the rate of filtration, the cleaning and all other operations may be carried on without disturbing the other beds.

Sand used for filtration contains particles of various sizes; it is the finest portion which mainly determines the efficiency of the sand for filtration. According to Hazen (1916), the finer 10 per cent on a weight basis has as much influence in filtration as the coarser 90 per cent. Therefore, the size of grain such that 10 per cent by weight of the particles are smaller and 90 per cent larger is designated as the *effective size*. It is determined by sifting a weighed amount of the sand through a series of sieves. The effective size of sand for slow sand filtration should be from 0.25 to 0.35 mm. Another important point in regard to the sand is its degree of uniformity; that is, whether the particles are mainly of the same size or whether there is a great range in their diameters. This is shown by the *uniformity coefficient*, a term used to designate the ratio of the size of grain than which 60 per cent of the sample is finer to the size than which 10 per cent is finer. Sand suitable for slow sand filters should have a uniformity coefficient of about 2.5.

The usual depth of the sand layer is three to four feet, and this is reduced by successive scrapings for the purpose of cleaning until it approaches 24 inches, when the sand is replaced. The depth of the water above the sand is usually four to six feet.

Probably the most important factor in the operation of a slow sand filter is the rate of filtration, which is 2,500,000 to 5,000,000 gallons per acre per day. The rate of filtration may be governed by automatic devices or may be controlled by hand. Careful attention is required in order to maintain a steady flow and a constant rate, which is essential, for sudden variations in rate are fatal to the successful purification of water by the slow sand process.

The resistance to flow in the sand is measured by the *loss of head*, which is the difference between the level of the water above and that below the sand layer as measured in water gauges. The loss of head increases as the filter clogs. When a filter is new or perfectly clean the loss of head is usually 0.2 to 0.3 foot; when it reaches a value at which the rate of filtration cannot be maintained the filters must be cleaned. Ordinarily, however, the filter is cleaned before this value is reached in order to avoid irregular performance.

The length of time a filter may run before the loss of head makes operation unprofitable and before the bed requires cleaning varies from a few days to many months.

*Efficiency and Control.* The efficiency of a sand filter is fairly measured by a comparison of the number of bacteria in the raw and filtered water. A properly operated slow sand filter will remove 98 or 99 per cent of the bacteria in the applied water when the latter contains as many as a few thousand bacteria per ml. If preliminary treatment is used, such as sedimentation or coagulation, the number of bacteria (standard plate count) in the effluent of a filter will usually be less than 100 per ml., and members of the coli-aerogenes group will usually be absent in 10 ml. of water. It is to be noted that all bacteria in the filtered water do not

represent those that actually pass through the sand. Some of them grow in the underdrains and gravel layer and are, so far as known, harmless.

The filtered water should normally be treated with chlorine. The dose required for disinfection of the filtered water is relatively small.

It is to be expected that the few slow sand filters now in operation will be replaced eventually by rapid sand filters, which produce a greater quantity of water from a smaller area at less cost, and which, furthermore, are able to treat waters which cannot be treated by slow sand filters. The main advantages still possessed by the slow sand filter over its competitor are less need for highly skilled operation, and a lower head requirement.

**Rapid Sand Filters.** The essential and characteristic features of rapid sand filtration are: (1) the addition of a chemical precipitant or coagulant to the water, followed by sedimentation; (2) passing the water rapidly through a layer of sand; (3) washing the sand when dirty by reversing the flow of water and in some cases using pneumatic or mechanical means of agitating the sand. The filters may be either of the gravity or the pressure type. The filtering sand is contained in a large wooden, iron, or concrete tank or box, usually built with a rectangular cross section. These filters are sometimes called mechanical filters, not only because the filtering sand is sometimes washed mechanically, but because the action more nearly approaches a mechanical straining, whereas biological processes may be important features in the purification of water passing through a slow sand filter (Baylis, 1937).

Rapid sand filters produce a minimum of 125 million gallons per acre daily of filtered water; the trend is toward even greater yields, as for example, at the Chicago plant where the rate is 250 million gallons per acre daily. Rapid sand filter plants are built up of many units of small size, the individual filters having an area from 0.01 to 0.1 of an acre. They are sometimes built in the open in warm climates but are usually housed. The sand is 24 to 36 inches deep and is underlaid with 12 to 18 inches of gravel in graded sizes.\* There is a trend toward the shallower beds. The effective size of the sand used varies from 0.35 to 0.60 mm., the usual size being about 0.45 mm., but there is a trend toward the use of coarser sands. The uniformity coefficient should be less than 1.8. As with a slow sand filter, the loss of head increases as the period of service is extended. Finally, it reaches a point where the rate of filtration can no longer be maintained. The filter is washed at or before this point, usually when the head loss has built up to 10 feet.

**Washing Filters.** The filters are washed by providing a reverse flow of water of sufficiently high velocity to lift and expand the bed of sand. The agitation and rubbing action to which the sand grains are thus subjected frees them from the accumulated coagulum, and this is carried off by the wash water. The usual rate of wash is about two to three cubic feet of water per minute per square foot of

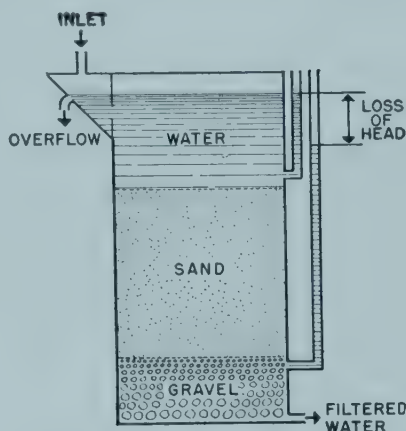


Fig. 39-2. Diagram illustrating "loss of head."

\* In some recent filters the gravel is replaced by porous plates and all or part of the sand by fine anthracite coal.



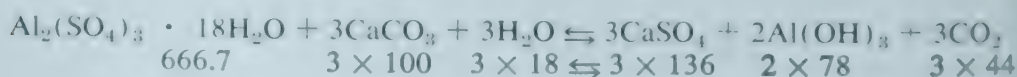
filter; the trend is toward coarser filter sands and consequently higher wash rates. The washing process consumes from 2 to 5 per cent of the total water filtered.

Some of the first rapid sand filters had revolving rakes to aid the washing process by agitation of the sand. These are now less frequently used. Some filter have been designed to use compressed air for the same purpose. The air is admitted through a separate distribution system below the sand bed. The most recent improvement in washing technic is the provision of surface wash, which is the application of a part of the wash water at high velocity to the surface of the sand bed, in such a way as to provide additional agitation of the sand. In one widely used system, high pressure jets are directed downward at the surface of the bed. Surface wash appears to justify the expense of installation; the sand is more thoroughly cleaned without much increase in the amount of wash water used and filter troubles, such as mudballs and cracking, are much reduced. The result has been a fairly widespread adoption of surface wash.

**COAGULANTS.** The *coagulants* used are aluminum sulphate, commonly called "filter alum," and occasionally ferric sulphate, ferric chloride, or ferrous sulphate (copperas) in conjunction with chlorine. The alkalinity present in the water reacts with the aluminum sulphate to form aluminum hydroxide, which is thrown out of solution as a flocculent, colloidal, jelly-like precipitate.

Bicarbonates or carbonates (alkalinity) are consumed by this reaction; one part of commercial filter alum consumes 0.45 part of alkalinity as  $\text{CaCO}_3$ . If the water does not contain sufficient natural alkalinity for the alum, lime or soda ash must be added. Although the stoichiometric reactions are not representative of the actual mechanism of coagulation, they are useful in approximating the quantity of natural or added alkalinity required, and the changes produced in the coagulated water.

The reaction for alum can be written as follows:



1 grain of alum per gallon = 143 lbs. per million gallons.

1 grain of alum per gallon = 17.1 parts per million parts of water.

1 grain of alum per gallon requires therefore

$$17.1 \times \frac{300}{666.7} = 7.7 \text{ parts per million of alkalinity expressed as } \text{CaCO}_3$$

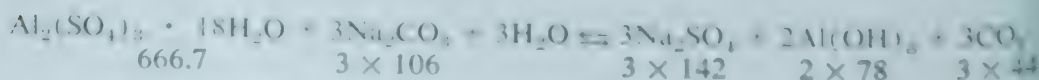
In water, however, the reaction is with bicarbonate:



Therefore 1 grain of alum per gallon liberates 6.8 parts per million  $\text{CO}_2$ .

Also, 1 grain of alum per gallon converts 7.7 parts per million bicarbonate alkalinity to 7.7 parts sulphate or incrustants, all expressed in terms of  $\text{CaCO}_3$ .

**Reaction using soda ash with alum:**



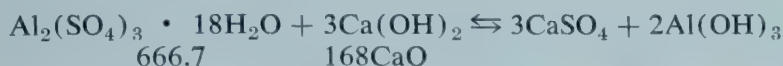
1 grain per gallon alum requires  $\frac{300}{666.7} \times 17.1 = 8.2 \text{ p.p.m. } \text{Na}_2\text{CO}_3$

1 p.p.m. = 8.3 lbs. per million gallons.

1 p.p.m. alkalinity as  $\text{Na}_2\text{CO}_3 = 8.3 \times \frac{100}{100} = 8.3 \text{ lbs. } \text{Na}_2\text{CO}_3 \text{ per mg.}$

1 grain per gallon alum liberates  $\frac{300}{666.7} \times 17.1 = 8.2 \text{ p.p.m. } \text{CO}_2$

Reaction using lime with alum:



1 grain per gallon alum requires  $\frac{168}{666.7}$  of 17.1 = 4.3 p.p.m. CaO = 36 lbs. per ng. CaO.

This liberates no  $\text{CO}_2$ .

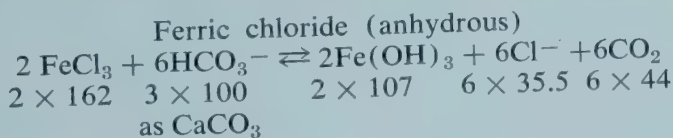
1 grain per gallon alum reacting with lime increases hardness 7.7 p.p.m. as  $\text{CaCO}_3$ .

If the natural or added alkalinity present in the water is insufficient to react with the alum added, two undesirable effects will occur. First, the hydrolysis of the excess aluminum salt, according to the reaction



will increase the acidity, or lower the pH value of the water, making it highly corrosive and otherwise undesirable. Second, since the solubility of  $\text{Al}(\text{OH})_3$  is increased as the pH is lowered, the amount of residual aluminum present in the water as  $\text{Al}^{+++}$  will be increased to objectionable levels. The residual aluminum causes after-precipitation of floc in mains and services and interferes with many industrial operations, notably dyeing. Aluminum hydroxide is an amphoteric substance; it is soluble in both acids and alkalies. Hence, if a great excess of alkaline reagent is added in coagulation, producing a high pH value, the result will also be an increase in the dissolved aluminum coming through the filters.

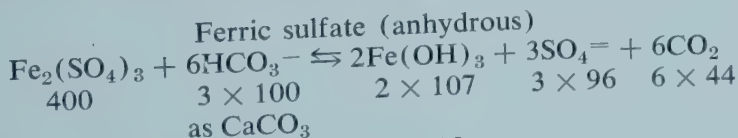
Coagulation with alum therefore requires a fairly delicate balance; the pH value of the coagulated water must not fall far outside the range 6.0 to 7.0. Ferric salts are not subject to this disadvantage; ferric hydroxide is quite insoluble over the pH range 4.0 to 12.0. Therefore, whenever it becomes necessary to coagulate water at low or high pH values, ferric salts are used. The stoichiometric reactions for the common ferric salts are given below:



grain per gallon of ferric chloride requires  $\frac{300}{324} \times 17.1 = 15.8$  p.p.m. of alkalinity as

$\text{CaCO}_3$

grain per gallon of ferric chloride liberates  $\frac{264}{324} \times 17.1 = 14$  p.p.m.  $\text{CO}_2$



grain per gallon of ferric sulfate requires  $\frac{300}{400} \times 17.1 = 12.8$  p.p.m. alkalinity as

$\text{CaCO}_3$

grain per gallon of ferric sulfate liberates  $\frac{264}{400} \times 17.1 = 11.3$  p.p.m. of  $\text{CO}_2$

Ferrous sulfate heptahydrate,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , commonly called copperas, is the cheapest source of soluble iron, but unfortunately iron in the divalent (ferrous) state is much less effective than trivalent (ferric) iron as a coagulant. A solution

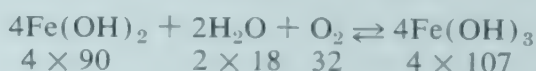
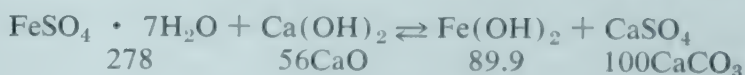


of copperas treated with chlorine has its iron content oxidized to the ferric state and is the equivalent of ferric chloride or ferric sulphate. The reaction is as follows:



1 part of chlorine oxidizes  $\frac{1,668}{213} = 7.8$  parts of copperas

At high pH values, ferrous iron is oxidized to the ferric state with fair rapidity by the dissolved oxygen of the water. This is the basis of coagulation by copperas and lime, a process which has been used extensively in the past, and is still resorted to under special circumstances. The stoichiometric reactions are as follows:



1 grain per gallon of copperas requires  $\frac{56}{278} \times 17.1 = 3.5$  p.p.m. of CaO or 4.6 p.p.m. of Ca(OH)<sub>2</sub>

This adds  $\frac{100}{278} \times 17.1 = 6.2$  p.p.m. of noncarbonate hardness expressed as CaCO<sub>3</sub>, and extracts from the water  $\frac{32}{4 \times 278} \times 17.1 = 0.49$  p.p.m. of oxygen.

The precipitated aluminum or ferric hydroxide clears the water of suspended matter, including bacteria and inorganic particles, by enmeshing them in a flocculent precipitate, which is subsequently deposited in the sedimentation basin, or on the filter. This is a somewhat oversimplified picture of coagulation; actually the effect of the trivalent aluminum or ferric ions in coagulating the colloidal particles present in the water into flocculent precipitates is more important than the formation of insoluble hydroxides. The "floc," so called, actually contains only a small proportion of aluminum or iron hydroxides.

The proper amount of coagulant in solution is added to the water by means of a calibrated orifice, or in dry form by means of some type of "dry feed" apparatus. Most waters require from a quarter of a grain to three grains of alum for each gallon of water; this is 4.3 to 51.3 parts per million, or 35.5 to 426 lbs. per million gallons. A few waters are difficult to coagulate and will require larger amounts.

The optimum amount of coagulant is dependent on a number of factors, many of them as yet imperfectly known. It cannot be predicted from analysis of the water, but must be determined by experiment or observation; furthermore, the coagulant demand of a single raw water source will vary from time to time. The most important of the factors determining coagulant demand are the amount and nature of the turbidity and color present, the pH value and alkalinity of the raw water, and its temperature. Laboratory equipment for making periodic tests of the response of the raw water to different amounts of coagulant is almost indispensable to the economical operation of a rapid sand filtration plant.

Coagulation of the raw water is followed by a holding period to allow the floc

to grow in size, and ultimately to settle out, prior to application of the water to the filter. An ideal installation would provide a rapid mix to disperse the coagulant in the water, then a period of slow stirring at velocities sufficiently high to accelerate the growth of floc particles by frequent collisions, but not great enough to rupture the floc, and finally a period of comparative quiescence to allow the enlarged floc to settle. In older installations, both flocculation and settling were effected by the provision of coagulation basins designed for retention periods of 2 to 6 hours, with no attempt to separate the two processes. Subsequently, a portion of this space was provided with mechanical flocculators (essentially, stirring devices operating at low speed) thus separating the flocculation and sedimentation stages. Material increases in coagulation efficiency resulted. A further reduction in the space and time required for coagulation has been brought about by the upward-flow or "sludge-blanket" flocculator, in which the water, with coagulant added, moves up through a hydraulically suspended blanket of previously formed floc. The newly formed small floc particles are picked up by the larger particles in the blanket, and the excess floc settles to the bottom of the device. This amounts to a recombining of the flocculation and sedimentation stages, but because of the intimate contact between water and floc, the efficiencies far exceed those obtained in the old style sedimentation basins. At present, the upward-flow coagulators exist largely as patented devices of several types.

Rapid sand filtration is the only known method of treating water from a very turbid or highly colored source. The process is particularly applicable to the muddy streams of our South and West and the highly colored waters of the Atlantic seaboard. It is also the only known method of treating waters heavily polluted by sewage or industrial wastes.

Rapid sand filters, when properly designed and operated, will remove from 5 to 99 per cent of the bacteria contained in the raw water. There are limits to the amount of raw-water pollution that can be successfully dealt with by rapid sand filtration or by any combination of treatment processes. This is well brought out in the papers of Streeter (1927, 1929, 1933). He observed in their various stages of treatment the efficiency and limitations of some 31 municipal filtration plants on the Ohio River and on the Great Lakes. He showed that the bacterial relationships between the quality of the raw, or influent water, and the corresponding quality of the effluent conformed to the equation:

$$E = c R^n$$

$R$  = bacterial content of the raw water

$E$  = corresponding bacterial content of the effluent

$c$  = an empirical constant defining value of  $E$  when  $R$  = unity

$n$  = an empirical constant defining the linear slope of the straight line representing the relationship between the logarithms of the two variables

The consistency with which the bacterial relationships observed in the plant studies conformed to this equation suggested that it represents a basic relationship which underlies water-purification processes in general and which is applicable both to individual stages of treatment and to combinations. The equation bears a close analogy to the Freundlich equation for the law governing adsorption phenomena. This further suggested to Streeter that water-purification processes, which



are essentially extractive ones, are probably subject to laws similar to those governing adsorption.

Results obtained from observation of the 31 plants gave bacterial relationships consistent with those predicted by the use of this equation.

In Table 39-1 are given the number of coliform organisms suggested by Streeter as the maxima permissible for Ohio River and Great Lakes waters if effluents that meet the primary requirement of the U. S. Public Health Service standard are to be obtained from the various combinations of treatment indicated.

Table 39-1. Limiting raw-water coliform index, and various combinations of treatment

Treatment	Limiting Raw-water Coliform Index per 100 ml. (Round Numbers)	
	Ohio River	Great Lakes
1. Chlorination alone	80	50
2. Coagulation, sedimentation and rapid sand filtration (without chlorination)	80	60
3. Same as (2) with prechlorination	3,500	no observation
4. Same as (2) with postchlorination	6,000	4,500
5. Same as (2) with both prechlorination and postchlorination	20,000	no observation
6. Same as (4) with double-stage sedimentation (relatively long period)	60,000	no observation

Adapted from Streeter, H. W., Pub. Health Rep., 48:396, 1953

**DIATOMITE FILTERS.** The diatomite filter for water purification is an outgrowth of industrial filtration practices. The water to be filtered is mixed with a comparatively large amount of diatomaceous earth and passed into a pressure shell, where it is forced through a porous septum. The diatomaceous earth is strained out and forms a filtering layer from one-sixteenth to one-fourth inch thick on the surface of the septum. If necessary, the septum can be precoated with the diatomaceous earth by filtering a heavily dosed portion of water to waste. As in the rapid sand filter, the head loss increases with the amount of water passing through, and when the loss reaches a specified amount, the diatomaceous earth layer is dislodged by reversing the flow through the septum and discharged with the backwash. A new cycle of operation is then begun. Rates of filtration are somewhat higher than those of the rapid sand filter, but at the very high rates sometimes used (15 gallons per minute per square foot), bacterial removals are not particularly good. Suitable effluents can be produced at lower rates.

The diatomite filter is considerably lower in weight and bulk than a rapid sand filter of comparable capacity, which makes it advantageous for mobile installations such as military field water supplies (Black and Spaulding, 1944). It must, however, have continuous supplies of diatomite. There is some evidence that it is more effective than the sand filter in removing cysts of *E. histolytica*. It is not likely that the diatomite filter can compete with the rapid sand filter in fixed installations except under unusual conditions.

**HOUSEHOLD FILTERS.** The small domestic filter attached to a household supply is a most unsatisfactory device and, fortunately, is nearly obsolete, except for

special applications such as the removal of precipitated iron. It is of no value in removing harmful bacteria, and in many cases has been known to increase rather than decrease the bacterial content of a water. An effective filter requires expert maintenance, which is not available in the home.

**Storage of Filtered Water.** Purified water stored in open reservoirs is subject to contamination by trespassers, birds and animals, dust, and surface washings. Open reservoirs must be especially carefully protected if no disinfection is provided beyond the reservoir. Another disadvantage of open storage reservoirs is the possibility of algal growths which may produce disagreeable tastes and odors. For these reasons filtered water is preferably stored in covered reservoirs, both at the plant and throughout the distribution system.

**Disinfection of Water.** It is now general practice to subject water for public consumption to the action of a disinfecting agent regardless of the purity of the water or the previous treatment it has undergone. The disinfection serves as a final barrier to the passage of any pathogenic organisms. Many disinfecting agents have been tried in the past, but elemental chlorine and the hypochlorites now hold a practical monopoly of the field by reason of their effectiveness, cheapness, and ease of application. Chlorination does, however, produce objectionable tastes in certain waters, so that a few other disinfecting agents are occasionally used. These will be discussed before taking up the subject of chlorination, but it is to be emphasized that their use is not nearly as extensive or successful as is often indicated in the literature.

**OZONE.** Ozone is an effective disinfecting agent. The amounts required are about the same as those of chlorine. It will not produce objectionable tastes in waters containing phenols and other compounds which give objectionable tastes when chlorine is used. It is produced by passing dry air through a corona discharge produced between electrodes to which a high voltage is applied. The reaction is  $O_2 \rightleftharpoons 2O_3$ . The ozone is transferred to the water by passing the ozonized air through the water. The major impediment to the development of ozonization of water has been the expense of the equipment and of the current required to operate it. The need for expert supervision over and above that provided by the plant operator has also been a factor. There is also a need for a dependable method of determining the amount of ozone present in the water. One of the shortcomings of the ozone process frequently cited is that it leaves no residual of germicide to give subsequent protection to the water, but it should be pointed out that the small residuals of chlorine carried by most water plants are also of dubious value against subsequent pollution.

Ozone probably owes its effectiveness as a disinfectant to its powerful oxidizing action. The same is true of its ability to eliminate substances having objectionable tastes when it is applied in sufficiently large amounts. If the problems of high cost of production and delicacy of the equipment can be overcome, ozonization may have a future in water treatment. Up to the present, a large proportion of the installations of the process have been subsequently abandoned.

**IONIC SILVER.** Small quantities of silver dissolved in water in the form of silver ion ( $Ag^+$ ) will kill bacteria; the amounts required are of the order of 0.015 to 0.05 parts per million. As with ozone, the principal advantage over chlorine disinfection is the absence of any tendency to produce objectionable tastes. The



process has received much attention, particularly in Europe, and many ways of introducing the silver into the water have been developed, for example, contact with silver coated sand or porcelain rings (Katadyn process), silver electrodes with periodic change of polarity (Electro-Katadyn process), and simple addition of silver nitrate. Disinfection by silver ion is very slow, requiring about an hour at 0.05 p.p.m., and is ineffective in the presence of organic matter. Practical use of the process is negligible at present.

**ULTRAVIOLET LIGHT.** Direct exposure to light of wave lengths below 2,800 Ångstrom units will kill bacteria in a few seconds, and even resistant spores are eliminated by slightly longer exposure. Light of suitable wave length may readily be produced by mercury arc lamps with tubes of quartz or special glasses with high transmission in the ultraviolet. The principal wave length of the light emitted by the mercury arc is 2,538 Ångstrom units. There have been a few attempts to sterilize water by passing it under or around banks of such lamps in shallow flumes. The depth of water must be five inches or less because of the rapid absorption of the ultraviolet rays by water. The process has failed in practice for several reasons, among which are the relatively high cost of operation, the difficulty of maintaining efficient operation of the lights, especially in the absence of any rapid test for efficiency, and the fact that even small quantities of color or turbidity in the water seriously diminish the effectiveness of the disinfection by absorbing the ultraviolet light.

**CHLORINATION.** Although the use of chlorine compounds as disinfectants and deodorants antedates 1854, when the British Royal Commission recommended the use of bleaching powder for deodorizing sewage, the use of chlorine compounds for disinfecting water was initiated in 1908 by G. A. Johnson. The water supply was that of the Chicago stock yards, and the compound used was chlorinated lime. In the same year, the process was applied to the water supply of Jersey City. In 1912, the water supply of Niagara Falls was disinfected by elemental chlorine, produced by electrolysis of brine, and compressed to liquid form in steel cylinders. The purity, stability, and low cost of liquid chlorine led to its rapid adoption by most water plants of any size, and today the use of chlorine compounds is substantially restricted to small or temporary installations. The types of chlorine derivatives now available for use are numerous, and they are listed below in the approximate order of their importance as water disinfectants.

Substance	Active Ingredients	Per Cent "available chlorine" *	Remarks
Liquid chlorine	$\text{Cl}_2$	100 —	.....
Calcium hypochlorite	$\text{Ca}(\text{OCl})_2$	70	.....
Sodium hypochlorite solution	$\text{NaOCl}$	4 to 5 or 16	Produced as a solution only
Ammonia chloramines	$\text{NHCl}_2$ $\text{NH}_2\text{Cl}$		Produced directly in water by reaction of $\text{Cl}_2$ and $\text{NH}_3$

\* "Available Chlorine" is actually a measure of oxidizing capacity expressed in terms of an equivalent amount of  $\text{Cl}_2$ .

leaching powder or chlorinated lime	CaClOCl	35	First compound used; relatively unstable
Chlorine dioxide	Cl <sub>2</sub> O	.....	Produced directly in water by reaction of Cl <sub>2</sub> and NaClO <sub>2</sub>
Organic chloramines	— NCl or — NCl <sub>2</sub>	.....	Special compounds of high stability and portability, for special uses. Examples: Halazone, HOOC-C <sub>6</sub> H <sub>4</sub> -SO <sub>2</sub> NCl <sub>2</sub> ; Succin-chlorimide, (CH <sub>2</sub> CO) <sub>2</sub> NCl; Chloramine T, CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> SO <sub>2</sub> Na NCl

*Liquid Chlorine.* Liquid chlorine is available at substantially 100 per cent purity in pressure containers holding from 10 to 2,000 lbs., and in tank cars holding 2,000 to 60,000 lbs. In water works practice the 100-, 150-, and 2,000-lb. containers are generally preferred. The chlorine is administered to the water by means of special patented devices which control a slow evaporation of gaseous chlorine from the cylinder into the device, dissolve the gaseous chlorine in a small flow of water, and then add the concentrated solution so produced to the main flow of water. The amounts of chlorine applied range from fractions of a part to several parts per million, depending on the character of the water to be disinfected.

The gaseous chlorine reaching the water is hydrolyzed immediately and, in the concentrations used in water disinfection, completely, according to the following reaction:



The hypochlorous acid so formed ionizes in part according to the following reaction:



The amount of ionization is governed by the pH value of the water, in conformance with the laws of chemical equilibrium.

Hence, the immediate result of dissolving gaseous chlorine in water is a solution which contains no chlorine as Cl<sub>2</sub>, but only hypochlorous acid (HOCl) and hypochlorite ion (OCl<sup>-</sup>). The distribution of the chlorine between these two forms is a function of the pH value of the water; at pH values below 5.0 all of it is present as HOCl, above 10.0 all exists as OCl<sup>-</sup>, and at pH 7.5 equal amounts of each are present. This has an important bearing on the efficiency of disinfection, as will be presently shown. A more complete discussion will be found in the papers of Fair and others (1947, 1948) and Griffin (1947).

Chlorine in the form of hypochlorous acid or hypochlorite ion is a powerful oxidizing agent and as such, reacts rapidly with any reducible organic matter or other reducing substances that may be present in the water. In such reactions, the chlorine is converted to chloride, and is no longer of value as a disinfectant. Hence, the amount of reducible substance in the water, measured in terms of the chlorine consumed, and referred to as the "chlorine demand" of the water, is a major factor in determining the amount of chlorine required to disinfect the water. The amount of unreacted chlorine remaining in the water at any specified time after addition of chlorine is termed "residual chlorine"; it is the amount of chlorine



still remaining as an effective disinfectant at this time. The Manual of Water Sanitation Practice of the U. S. Public Health Service issued in 1946 recommends that a chlorine residual of 0.2 p.p.m. should be present after 20 minutes; this will normally ensure adequate disinfection. The chlorine residual is measured by means of the ortho-tolidine test or the ortho-tolidine-arsenite test as described in the tenth edition of Standard Methods for the Examination of Water and Sewage.

The one great disadvantage of chlorine disinfection is the tendency of chlorine to react with certain substances often present in water to produce compounds of objectionable taste and odor. These tastes and odors are regularly attributed by the public to chlorine itself, but actually pure chlorine is detectable by most persons only at concentrations far above those usually remaining in waters reaching the consumer. Few of these taste-producing compounds have been identified as yet, but phenol and its homologues are well-known offenders. The presence of a few parts per billion of phenol in a water will produce a characteristic medicinal or "iodoform" taste when the water is chlorinated. Certain unidentified components present in beet-sugar plant wastes will also produce taste and odor upon chlorination, even when the dilution is extremely high. Taste and odor production as a result of chlorination is a serious problem in many water plants treating waters containing even relatively small concentrations of industrial wastes. The various methods which have been devised to overcome this problem will be discussed subsequently.

Chlorine is a highly toxic gas; exposure to 40 to 60 parts per million in air for as much as 30 minutes is dangerous, and 1,000 parts per million (0.1 per cent) produces death in a few minutes. It is also highly corrosive to metals, and tends to create leaks. Hence, separate chlorinator rooms with forced-draft ventilation are highly desirable, and the provision of suitable gas masks is mandatory. The precautions to be used in handling chlorine have been so well stressed by the manufacturers of chlorine and chlorinator equipment and by a special committee of the American Water Works Association (1935), that very few accidents have taken place, despite the large numbers of liquid chlorine installations.

*Hypochlorites.* The hypochlorites of both sodium and calcium are used extensively as alternatives to liquid chlorine. Bleaching powder or chlorinated lime is a monohypochlorite of calcium,  $\text{CaClOCl}$ , produced by passing chlorine gas over hydrated lime. It is a hygroscopic white powder which readily absorbs both moisture and carbon dioxide from the air, with liberation of chlorine and consequent loss of strength. It has been largely replaced by the dihypochlorite,  $\text{Ca(OCl)}_2$ , which is produced by a complex crystallization process, and marketed under various trade names. This is a white powder which has less tendency to lose strength through absorption of moisture and carbon dioxide and, in addition, contains twice as much available chlorine as bleaching powder. The hypochlorites of calcium are fed by dissolving them in water, allowing any calcium carbonate sludge to settle, and adding the clear solution, containing 1 to 3 per cent of chlorine, to the water to be disinfected by means of orifices or proportioning pumps which control the quantity added.

Sodium hypochlorite is available as a solution containing  $\text{NaOCl}$  and some  $\text{NaOH}$ , two strengths are marketed, one containing about 4 per cent available chlorine, and the other about 16 per cent. The solution may be purchased or

ade at the plant by electrolyzing a sodium chloride solution. It is relatively un-  
able and has a high proportion of inert ingredients, mostly water; long-distance  
ipment is inadvisable. It is fed by diluting as desired, and adding the diluted  
lution to the water in the same manner as the calcium hypochlorite solutions.

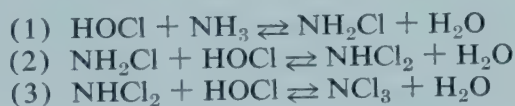
When hypochlorites are added to water, they ionize immediately to hypo-  
chlorite ion ( $\text{OCl}^-$ ) and calcium or sodium ions. The hypochlorite ion then dis-  
tributes itself between  $\text{HOCl}$  and  $\text{OCl}^-$  by the same equilibrium as previously noted:



accordance with the pH value of the water. Hence the end result is precisely  
e same as that secured by the addition of liquid chlorine, with a slight modifica-  
on in that hypochlorites tend to raise the pH of the water because of alkaline  
ubstances present along with them, whereas liquid chlorine tends to reduce the  
H value slightly.

Since the end products in the water are identical, the comments on chlorine  
demand and on taste and odor production made in the discussion of liquid chlorine  
apply with equal force to the hypochlorites. Under the same conditions of tem-  
perature and pH value the disinfecting efficiencies of liquid chlorine and the hypo-  
chlorites are also identical.

*Ammonia Chloramines.* When ammonia or its salts are present in water to  
which chlorine or hypochlorites are added, chloramines are formed according to  
the following reactions:



Reaction (1), resulting in the formation of monochloramine ( $\text{NH}_2\text{Cl}$ ) is about  
90 per cent completed in one minute at ordinary water temperatures and in the  
pH range 6 to 8. Reaction (2) is favored by somewhat more acid conditions;  
dichloramine ( $\text{NHCl}_2$ ) predominates only at pH values in the vicinity of 5 to 6.  
The range of reaction (3) is yet imperfectly understood, but no very great pro-  
portion of nitrogen trichloride ( $\text{NCl}_3$ ) is believed to be present except at pH values  
well below 5.0.

Chloramines are much less active as oxidizing agents than hypochlorous acid.  
This has two results: the effective "chlorine demand" of the water is materially  
less for chloramines, so that chloramine residuals persist for a much longer time;  
also, the chloramines do not react as readily with substances like phenol to pro-  
duce objectionable tastes and odors. As a result, chloramine disinfection has been  
adopted by many plants where persistent residuals are desired or where taste and  
odor difficulties are experienced when chlorine alone is used. The ammonia re-  
quired is added in the form of ammonia gas, aqua ammonia, or ammonium salts.  
Any ammonium compound naturally present in the water will also be converted  
to chloramines upon the addition of chlorine to the water.

Chloramines are, unfortunately, much less effective as disinfectants than hypo-  
chlorous acid. The Manual of Water Sanitation Practice of the U. S. Public Health  
Service recommends that the residual chlorine should be two parts per million at  
the end of three hours to secure effective disinfection when chloramines are em-  
ployed. A comparison with the recommendation previously cited for chlorine alone



will illustrate the very great difference in effectiveness. Dichloramine is more effective than monochloramine, but it is not formed in substantial amounts except at rather low pH values. A more complete discussion will be found in the paper of Fair and others (1948).

**SUPERCHLORINATION AND DECHLORINATION; BREAKPOINT CHLORINATION.** If sufficiently large amounts of chlorine are added to water, the result is the complete elimination of the chlorine demand by oxidation of reducing substances and by the satisfaction of other substances capable of reacting with chlorine. In the course of this process, taste- and odor-producing compounds are destroyed or rendered innocuous, and any chlorine remaining exists only as hypochlorous acid or hypochlorite. Disinfecting activity is also at its highest efficiency at this point, since there are no competing reactions.

A few plants faced with serious taste and odor problems have, in the past, resorted to the practice of superchlorination and dechlorination, which involves the addition of an excess of chlorine, followed, after a suitable contact period, by removal of the bulk of the remaining chlorine. Removal is effected by the controlled addition of some reducing agent such as sulphur dioxide, sodium sulphite, or sodium thiosulphate. Activated carbon has also been used as a dechlorinating agent. The process has been successful with many difficult waters, but is somewhat cumbersome, and is being replaced by the newly developed "breakpoint" method.

"Breakpoint chlorination," so called, consists essentially of careful adjustment of the chlorine added to the water so that the total chlorine demand is eliminated and a very slight residual remains. The addition of successive increments of chlorine to water, especially if the water contains ammonia, results in a residual chlorine content which at first increases as the chlorine dose increases. This residual consists principally of ammonia chloramines and similar chlorine derivatives. However, as the chlorine dose is increased further, these chloramines are destroyed by the additional chlorine, and the observed residual begins to decrease. The mechanism of this destruction is as yet somewhat obscure, but it apparently involves oxidation of the nitrogen of the chloramines. This decrease in residual with observed chlorine dose continues until the residual reaches nearly zero; this is the so-called "breakpoint." Beyond this point, any additional chlorine dose appears in its entirety as residual chlorine; furthermore, all of this residual exists in the form of hypochlorous acid or hypochlorite. Thus, the end point is substantially the same as that reached by superchlorination and dechlorination. A highly effective disinfection is secured, and in most cases the taste and odor problem is eliminated. The only difficulty lies in adjusting the dose of chlorine exactly to the breakpoint, but unless the water is subject to rapid changes in composition, it is not a serious one. The breakpoint process is gaining favor rapidly because it requires no additional equipment above that required for simple chlorination.

**OTHER HALOGEN DISINFECTING AGENTS.** Chlorine dioxide, an oxidizing agent more powerful than hypochlorous acid, is formed in water by the addition of sodium chlorite ( $\text{NaClO}_2$ ) and liquid chlorine. It has recently been shown to be very effective in the destruction of resistant taste- and odor-producing compounds and is being used in a few plants in combination with chlorine to produce a palatable disinfected water.

A number of organic chloramines, such as halazone ( $\text{HOOC-C}_6\text{H}_4\text{-SO}_2\text{NCl}_2$ ),

accinchlorimide  $[(\text{CH}_2\text{CO})_2\text{NCl}]$ , and chloramine T,  $(\text{CH}_3-\text{C}_6\text{H}_4-\text{SO}_2\text{NaNCl})$ , can be made into tablets of relatively high stability which are useful for emergency disinfection of small quantities of water. Elemental iodine can be similarly used; its effectiveness in disinfection is but slightly less than chlorine, weight for weight, and it has less tendency to produce objectionable tastes and odors. Ordinary tincture of iodine can be used for water disinfection. A recent development is a tablet containing a glycine-iodine compound,  $(\text{NH}_2\text{CH}_2\text{COOH})_4\text{HI} \cdot 1.25\text{I}_2$ , called Iobalaine. This tablet, which is more stable than the organic chloramines, releases iodine in water, and offers many advantages for field and emergency disinfection. Bromine has been applied experimentally to water disinfection; it is effective, but appears to offer no advantage over chlorine, and is more expensive.

**FACTORS AFFECTING THE EFFICIENCY OF DISINFECTION.** The organisms which are to be eliminated by disinfection of water are varied in character; the following list comprises those known at present:

1. The enteric bacteria, comprising members of the groups *Salmonella*, *Shigella*, and *Vibrio*.
2. The intestinal protozoa, of which *Entamoeba histolytica* is the most common.
3. A few worms—for example, the schistosomes.
4. Viruses—for example, that of infectious hepatitis.
5. Coliform organisms which, although not pathogens, are the primary indices of contamination of water.

These organisms vary widely in resistance to disinfection; the enteric bacteria are most easily destroyed by chlorine compounds, and the coliforms are comparable with them. The cysts of *E. histolytica* are the most resistant organisms known at present, and should be employed more frequently as indicators in studies of water-disinfecting agents. Schistosomes are comparatively easily destroyed when swimming; the resistance of the viruses is but little known, but it is indicated to be at least lower than that of *E. histolytica* cysts.

Given a specific organism, a specific disinfecting agent, and a fixed water temperature, the disinfecting activity is a time-concentration relationship which can be expressed as follows (Fair and others, 1948):

$$C^n t = \text{constant}$$

where  $C$  represents the concentration of disinfectant in the water,  $t$ , the time to achieve a given percentage of the organisms present, and,  $n$ , a numerical exponent dependent on organism, disinfectant, and water temperature. In all studies made to date,  $n$  varies from 0.75 to 2.00, with 1.00 as the most common value. When  $n = 1.00$ , the implication is that contact time and concentration of disinfectant are of equal importance; if  $n$  is less than 1, time is of greater importance than concentration, and if  $n$  is greater than 1, concentration is more important than time. Lowering the temperature of the water materially decreases the rate of kill; a few complete studies that have been made indicate that the rate is approximately halved for each  $10^\circ \text{C}$  decrease in temperature. This demands a considerable increase in concentration of disinfectant in cold waters if suitable efficiencies are to be secured.

Much has been learned in the last few years about the relative disinfecting efficiencies of the various forms that chlorine assumes in water. For example, it



has been known for a long time that disinfection by chlorine is hindered by high pH values. The explanation lies in the fact that the distribution of chlorine between HOCl and OCl<sup>-</sup> ion is governed by the pH value of the water. HOCl is many times as effective, per unit of chlorine, as is OCl<sup>-</sup>, but a high pH value transforms most of the chlorine into OCl<sup>-</sup>. The rate of kill of an organism by the system HOCl, OCl<sup>-</sup> can actually be formulated in terms of the known distribution ratio as governed by pH value (Fair and others, 1948).

The effectiveness of the chloramines is also materially less than that of HOCl at equal concentrations of "available chlorine." For the enteric bacteria, HOCl appears to be 80 to 100 times as effective as dichloramine, the most active of the ammonia chloramines. Thus the success of superchlorination-dechlorination and "breakpoint" chlorination is demonstrated to be based on sound theoretical considerations, since both replace chloramine residuals with uncombined HOCl. The importance of differentiating between chlorine "residuals" consisting of uncombined HOCl and those consisting of chloramines is also demonstrated; this is recognized in the tenth edition of Standard Methods for the Examination of Water and Sewage by including several methods for differentiation.

**Corrective Treatment for Corrosion.** One of the most important phases of water treatment is the correction of corrosive quality. All metals tend to dissolve in any water to some extent, but waters which are soft and low in pH value are especially active. Furthermore, iron and steel, which are still the metals most generally used for piping, are highly susceptible to subaqueous corrosion, and although such metals as copper, brass, and lead are less readily attacked, the corrosion products may be objectionable or even dangerous in drinking water. The correction of corrosiveness is of importance in two ways: (1) from the standpoint of protection of the pipes, which tend to clog with the products of corrosion or to fail because of penetration; and (2) from the standpoint of protection of the quality of the water, which is debased by the presence in solution and suspension of metallic salts derived from the pipes.

Cast-iron pipes are commonly used in municipal water-distribution systems. They may be protected by coating them with tar, bitumen, or cement before and even after installation. All pipes may be protected during use by treating the water in such a way that thin films of certain substances are continuously maintained on the pipes, which are thereby protected from corrosive action by the water. The most common type of treatment is that which produces a film of calcium carbonate. This is accomplished by adding to the water prior to delivery to the system either lime, sodium carbonate, or both, to combine with carbon dioxide and bicarbonate of the water, forming calcium carbonate slightly in excess of saturation requirement at the final pH value. Experiments by Baylis (1927) have shown that this requirement varies between about 20 and 300 parts of calcium carbonate per million in the range pH 9 to pH 7. The chemical equilibria have been worked out by Langelier (1936, 1946), and further developed by others (Hoover, 1938; Moore, 1938), so that the amount of treatment necessary can be predicted from an analysis of the water. This treatment requires reasonably accurate control, for excessive treatment causes heavy incrustation of the pipes, and insufficient treatment permits corrosion.

Sodium silicate may also be added to water to inhibit corrosion; it forms a protective film composed of calcium silicate. If the water is low in calcium, lime may be used with the sodium silicate. Sodium poly-metaphosphate and certain complex sodium pyrophosphates are now used extensively for corrosion control; they produce films of calcium metaphosphates or pyrophosphates that are very effective on ferrous metals. They have advantages over the calcium carbonate treatments in that the amounts of chemical used are very small, and no incrustation results from overtreatment. Any of the treatments previously mentioned will, properly applied, reduce the corrosive attack of a water on piping to a negligible quantity, but none of them will prevent all corrosion, and for any particular case, one will usually prove better than the others.

**Copper Sulfate.** The use of copper sulfate to control algal growths in drinking waters was first proposed by George T. Moore of the United States Department of Agriculture in 1904. It has proved to be valuable for the elimination of taste- and odor-producing algae from reservoirs.

The copper sulfate is applied in the proportion of 0.1 to 1.0 part per million. The concentration required depends largely on the algal species to be controlled. Some of the copper is precipitated and settles to the bottom and in this way is removed from the water. If the water is afterwards filtered most of the remaining copper is removed. The copper remaining in the water in the absence of filtration is so minute that there is no evidence of real danger in using it in this way or even its occasional use in somewhat larger doses where the water is very bad. Copper is not an accumulative poison. Further, more of it is found in milk and some other foods than in a water treated with copper sulfate for the removal of algae.

The usual method of applying the copper is to place weighed quantities of copper sulfate in loose cloth bags and to tow them back and forth with boats through the water of the reservoir until the material is dissolved. It can also be cast over the water surface, or sprayed in the form of a solution. While the copper kills some species of organisms in the amounts used, it has little effect on others. In fact, it permits the growth of certain species by removing the guarding symbionts, thus clearing the way for stronger growths of the forms that are not directly affected. Copper sulfate may, therefore, entirely change the flora of a reservoir. This change is frequently accompanied by a great improvement in odors and tastes. On the other hand, the destruction or suppression of one species may be followed in a few weeks by an overgrowth of an equally objectionable and noisier form. A regular program of treatment, based on continued microscopic counts, is essential for continuous successful control of algae in a reservoir.

**Activated Carbon.** One of the most effective methods of dealing with tastes and odors in water supplies is that which employs activated carbon. This reagent acts both as a preventive and as a remover of these qualities, in that it will adsorb organic constituents that later react to give taste or odor, as well as adsorbing compounds which already have made themselves evident. Thus, the chlorophenols may be prevented by the use of activated carbon to take out phenolic compounds before the application of chlorine, while vegetable, musty and chlorine odors may be removed to improve physical quality.

Ordinary carbon, such as charcoal, was widely used in the nineteenth century in the form of filters for removal of bacteria, odor and color from water, but the



efficiency was not great and the life of the material not long. Chars of high adsorbing activity, hundreds of times greater than that of charcoal, were developed during 1910 to 1920. The general name of "activated carbon" was applied to these materials. They were first used in the purification of a wide range of products such as foods, chemicals and pharmaceutical preparations and as the active principle of gas masks. Research by Baylis (1929) in this country, Imhoff and Sierp in Germany, and others (American Water Works Association, 1938; Braidech, 1938; Helbig, 1938; Smith, 1938; Sigworth, 1943), proved the power of activated carbon to remove from water phenolic compounds and chlorine. Later work showed that this reagent will also take out odor- and taste-producing substances derived from algal growths and from dead vegetation. The removal is nearer to being complete by this process than it is by any other now known. Costly or complicated equipment is not necessary for the purpose. The cost of the carbon itself is the principal consideration.

Some of the early installations used beds of granular activated carbon through which the water was filtered. Such a practice involves a considerable initial outlay for material and its frequent removal or regeneration when it becomes charged with adsorbed impurities. Present practice in most cases makes use of a powdered activated carbon which is added to the water by means of a dry-feed apparatus to which is attached a water ejector. Obviously such a method of application is restricted to rapid sand filter plants.

Powdered activated carbon is generally a vegetable char made from a variety of woods, waste liquors from paper manufacture, nut shells or other vegetable products. It is activated by superheated steam or other heat methods. Activated carbon used for water purification is a more or less pure form of carbon which has a high adsorptive capacity for foreign molecules, due largely to its porous, capillary structure which presents an enormous total surface. It is light, weighing 10 or 11 pounds to the cubic foot, and it is fine; over 90 per cent of it will pass a 200-mesh sieve. The powder has a low apparent density (about 0.2) which causes it to settle slowly and to give sustained action. It functions by the power of adsorption whereby the carbon surface exhibits greater attraction for impurities in the water than does the water itself.

The amount of powdered activated carbon necessary to remove taste- and odor-producing substances has been found to be between 5 and 24 pounds per million gallons in the majority of cases. Occasionally more is required.

The point of application differs with local conditions and must be carefully selected. In practice it varies, being: (1) directly on the filters, (2) in the settling basin, (3) midway in the coagulation process, or (4) with the coagulant. The most common procedure by far is the latter, the activated carbon either being mixed with the coagulant or being separately added to the water at about the same point as the coagulant. There are two principal advantages in method (4). It follows: (1) Only a small amount of carbon reaches the filters and so excessive losses of head do not result as when adding carbon directly to the filters, and (2) The sludge in the sedimentation basin shows less tendency to putrefy in the presence of carbon, so that taste and odor troubles from this source are minimized. However, a part of the carbon is rapidly taken up by the floc, so that the

efficiency of a unit of carbon in removing taste and odor is less in method (4) than in methods (1) or (2).

Treatment with activated carbon is the most widely used method of controlling taste and odor. The cost is moderate for most waters, the method of application is simple, and the results in many cases are striking. A few waters are resistant to carbon treatment, in the sense that excessive amounts are required to make the water palatable. For further details, the reader is referred to the report of the American Water Works Association Subcommittee on Activated Carbon (1938).

There are also several other water-treatment processes that may be applied in special circumstances. Among these may be mentioned softening, which has been discussed in Chapter 37 on Sanitary Analysis, and the removal or addition of fluoride to control defects in tooth structure caused by an excess or deficiency of this element. Fluoridation and defluoridation are discussed in Chapter 40.

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## WATER AND ITS RELATION TO DISEASE

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Water is a vehicle for certain infections such as cholera, typhoid fever, dysentery and other diseases having their primary seat in the digestive tract (see Chapter 3). It may carry inorganic poisons such as lead, or substances such as nitrate, which, when present in large amounts, is dangerous to infants. It may be responsible for certain nutritional and dietetic disorders that are less well understood. It may lack qualities which bring about derangements of metabolism resulting in such conditions as goiter. It is also occasionally responsible for conveying animal parasites, amebae, worms, etc. (see Chapter 3). From time to time new troubles are disclosed—epidemics of leptospirosis and of infectious hepatitis have been traced to water, and it has been demonstrated that excessive amounts of fluorine in water are the cause of mottled enamel of teeth; while inadequate amounts are associated with high rates of dental caries.

While water has an established place among the carriers of certain infections, it has not a supreme or exclusive place, and this should be kept carefully before us. The tendency to exaggerate the importance of water as a bearer of disease and death has sometimes led to overstatement. The facts are bad enough and do not require extravagant language to emphasize their importance. The greatest danger in water is pollution from human sources. All the discharges from the body (urine, feces, expectoration, secretions from the nose, and washings from the skin) find their way sooner or later into our streams and other bodies of water, especially where modern water-carriage systems are installed for the disposal of wastes. All sewage-polluted water must be regarded as dangerous, whether there are any known cases of typhoid fever on the watershed or not. It is highly probable that the sewage of large communities contains typhoid bacilli and other disease organisms in larger or smaller numbers, because even when no overt cases appear carriers and missed cases may be expected.

Water differs in several essential particulars from any other article of diet. Above all, it is partaken of raw, while perhaps 90 per cent of all our other food is disinfected by cooking before it is used. Again, it is a vehicle which comes in contact with many objects spread over broad areas, and it is the natural vehicle for the removal of wastes from these areas.

### NONSPECIFIC DISEASES DUE TO WATER

Impure water may be responsible for disorders other than specific gastrointestinal infections, but these disorders are obscure and are generally overlooked.



It is not always plain just what quality or what impurity in the water is responsible for these nonspecific disorders, and the diseases themselves may present a vague and ill-defined clinical picture.

A turbid, malodorous, or unpalatable water may not in itself be particularly injurious to health, but, on account of its unattractive appearance or repulsive condition, less may be taken than is necessary for the maintenance of good health or recourse may be taken to more palatable waters that are less safe. In this way water may be indirectly responsible for harm. The drinking of too little water is a common dietetic error.

*Organic matter* in the quantities usually contained in a natural water is not of itself harmful. Excessive organic matter, on the other hand, has been regarded with some suspicion, even when it is of natural origin. No positive evidence has ever been obtained to relate gastro-intestinal disturbances to natural organic matter except in the cases of excessive growths of certain of the blue-green algae (*Anabaena*, *Aphanizomenon*). These algae contain a toxic substance which has been fatal to cattle; instances of human illness so produced are rare, because the concentration of algal growth required to produce an effect is such as to cause rejection of the water on esthetic grounds. Even though the case is not clear, sanitary engineers have tended to err on the safe side by condemning waters containing much organic matter, or by treating them to remove it.

As far as the *inorganic impurities* usually found in water are concerned, the chlorides, carbonates, sulphates, and silicates, and lime, magnesia, and aluminum can scarcely be harmful in the amounts ordinarily found. In fact, most of the mineral matter, especially lime, carried by water is needed by the body. The amount secured in this manner, however, is negligible in comparison to that secured from foods. The trace of iodine in water may be an important source of this element in the diet, unless other sources are purposely provided. It is commonly stated that water containing 500 parts per million of clay and silt is unfit for drinking purposes on account of its irritating effects upon the gastro-intestinal tract; but beyond this probability, natural turbidity is of no special sanitary significance. Turbidity due to wastes may contain harmful substances.

Repeated attempts to correlate the formation of concretions such as urinary and biliary calculi with the inorganic salts in hard water have not been successful. Biliary calculi usually form about a colon bacillus or a typhoid bacillus or about some pathological particle as a nucleus. Urinary calculi probably have a similar pathogenesis. There is no known relation, therefore, between these concretions in the body and the inorganic salts in water, even those in a very hard water. Change from a soft to a hard water or vice versa may cause disturbance of bowel functions. Magnesium salts and sulphates in particular act as cathartics.

**Dental Fluorosis.** It has been conclusively demonstrated that the presence of fluoride in drinking water has profound effects on the structure and resistance to decay of the teeth. These effects are exerted in infancy and early childhood when the teeth are in process of formation, and there is no evidence that adult teeth are influenced. The effects are manifested in two ways: an excess of fluoride in the drinking water produces dental fluorosis, or in popular language, "mottled enamel," whereas a deficiency of fluoride has been recently demonstrated to increase the susceptibility of the teeth to caries.

Dental fluorosis was the first to be discovered (Smith, 1935). It usually takes the form of a modification of the tooth enamel to produce brown or yellow stains, or an unnatural opaque white appearance, or occasionally a blackening. The teeth are otherwise normal, but the stain is permanent. However, very large amounts occasionally produce disintegration in tooth structure. Dental fluorosis has been produced experimentally by the addition of sodium fluoride to the drinking water of white rats (Dean and others, 1934, 1935; Sebrell and others, 1935). It is endemic in several regions of the United States (Dean, 1933), and has been demonstrated to occur wherever the fluoride content of the water exceeds 1.5 parts per million as F. The incidence is directly related to the concentration of fluoride; for example, at Lubbock, Texas, where the concentration was 4 parts per million, about 97 per cent of the children were affected, whereas in certain Ohio towns where the concentration was 1.5 to 2.0 parts per million, the incidence was 20 to 30 per cent.

Surface waters are almost always low in fluorides; concentrations high enough to induce dental fluorosis occur only in deep wells in special aquifers. These aquifers are not of one geological type; for example, in Ohio and Florida, limestones are responsible, whereas in the Dakotas, Kansas, and Nebraska, a specific type of "Dakota" sandstone provides the fluoride. The fluoride-bearing aquifers are sufficiently widely, though irregularly, distributed to constitute a significant problem. It is estimated that over a million people are dependent on water supplies containing over 1.5 parts per million of fluoride.

Extensive research has revealed a number of possible methods of treating water to reduce the fluoride content of high fluoride water to tolerable levels, but these methods are complex and costly (Maier, 1947). The only one widely used at present is based on the fact that in softening hard waters, fluoride is removed along with magnesium in a direct relationship to the amount of magnesium taken out in the softening process. Empirically, the amount of fluoride removed is equal to  $0.7 F \sqrt{Mg}$ , where F represents the parts per million of fluoride initially present and Mg, the parts per million of magnesium taken out by the softening process. The water must be treated to a caustic alkalinity of 30 parts per million, and a pH value of 10.5; hence recarbonation is necessary. Few waters contain enough natural magnesium to effect the desired removal of fluoride, so that magnesium must be added prior to softening, in the form of dolomitic lime, magnesia, or epsom salt. The process is suitable for hard waters containing less than 4 parts per million fluoride (Scott and others, 1937).

For soft fluoride-bearing waters, a reversible exchange process, similar in nature to the zeolite process of water softening, but using granules of specially-processed calcium phosphate, has been proposed. The material takes up fluoride from the water, and is regenerated by a caustic soda solution, followed by a carbon dioxide solution. The process is effective, as demonstrated by a few plants in operation, but present costs appear to be high. Other ion-exchange processes have shown possibilities, but are as yet incompletely developed.

In the course of investigation of dental fluorosis, it became apparent that the prevalence of dental caries (tooth decay) was significantly less in areas where the water was high in fluoride than for the country at large. Further study demonstrated that, like fluorosis, the effect of fluoride in reducing susceptibility to caries



was apparent only in those who consumed the water during the period of tooth formation, and that the resistance to caries was probably carried over into later life. For example, Dean (1949) and Dean and others (1942) were able to demonstrate that 7,000 children using water containing 1.0 to 1.5 parts per million of natural fluoride showed an incidence of caries 50 to 65 per cent less than the national average.

The result of this discovery has been an increasing interest in the addition of soluble fluoride, usually in the form of sodium fluoride, to water supplies of low fluoride content. The desirable level of fluoride concentration is considered to be about 1.0 part per million; at this level, the danger of dental fluorosis appears to be negligible. Controlled studies on the effect of such additions are in progress, and in many communities fluoride addition has been adopted on an empirical basis. Such evidence as has been collected so far is highly favorable; reductions in caries of 50 to 60 per cent, as compared with neighboring towns used as controls, have been secured by fluoridation over test periods of five to seven years (Fluoridation as a Public Health Measure, 1954). The addition of fluoride in such small amounts is quite inexpensive; far less per person per year than the cost of a single filling. Since sodium fluoride is poisonous at high concentrations and can produce dental fluorosis at levels not far above that desired for caries prevention, it is obvious that careful control is imperative. The substitution of sodium fluosilicate ( $\text{Na}_2\text{SiF}_6$ ) for sodium fluoride offers some reduction in cost and a considerable reduction in toxicity; it may replace the sodium fluoride when studies on its effectiveness are complete.

**Infant Methemoglobinemia.** Nitrate had always been regarded as a harmless constituent of water until the observations of Comly (1945) led him to suspect it as the cause of certain cases of methemoglobinemia in infants fed on artificial formulae containing well water. Further investigation by others confirmed Comly's hypothesis; several cases were recorded where the condition of the infant cleared up on removal of the suspected water, only to reappear when its use was resumed. In all cases investigated, the condition was associated with the presence of a high concentration of nitrate nitrogen (20 p.p.m. or more) in the water. It was also produced experimentally by feeding to infants formulas containing water to which nitrates had been added.

The mechanism of the disease is believed to be as follows: in infants in whom the pH of the gastric juice is relatively high (over 4.9), nitrate-reducing bacteria grow in the intestine, producing nitrite, which is absorbed in the blood stream. The nitrite combines with the hemoglobin, rendering it incapable of absorbing oxygen, and thus producing cyanosis (Cornblath and Hartmann, 1948). If ingestion of nitrates is continued, death may result; the case fatality rate appears to be about 10 per cent. The condition is largely confined to infants of less than two months of age, and is unusual in infants over six months of age; it is unknown among adults except in cases of excessive ingestion of certain nitrogen-containing drugs and chemicals.

The dangerous level of nitrate concentration is believed to begin at about 20 parts per million as nitrogen, although in most of the cases recorded, the observed concentrations have been in excess of 50 parts per million (American Public Health Association, 1950). Variations in individual susceptibility, amount of water consumed in proportion to body weight, and method of preparation of formulae

make the exact establishment of safe limits somewhat difficult. Furthermore, the analyses may frequently not represent the actual nitrate concentration at the time onset of the disease. However, since only two or three incompletely authenticated cases out of several hundred investigated appear to be associated with less than 20 parts per million, it is probable that this represents a reasonably safe limit.

The disease has in all cases been related to private water supplies, principally in rural areas; no public supplies have been implicated. The waters involved are exclusively well waters, with shallow dug wells predominating. Inferior sanitary condition of the well is frequently, but not always, observed. A few deep drilled wells without sanitary defects have been found to contain high nitrates. No surface supplies containing dangerous amounts of nitrate have been found. The source of the large concentrations of nitrate nitrogen in wells appears to be mainly that leached from rich and well-fertilized soils, rather than nearby pollution. The nitrate nitrogen concentrations found in shallow ground waters in farm areas are surprisingly high; values up to 1,000 parts per million have been observed.

The geographical occurrence of cases of methemoglobinemia is peculiar. The cases are concentrated in the North Central United States and Canada. This distribution is as yet unexplained, since waters of high nitrate concentration are known to exist in other regions, from which cases have not so far been reported. It may be that differences in the character of the nitrate nitrogen exist in different regions, or that additional factors must be present in the water before the disease can be produced. On the other hand, the discrepancy in distribution may be due to regional differences in feeding habits or to inadequate reporting. In any case, it is evident that further investigation is required.

**Lead Poisoning.** Lead is practically never found in natural waters. The source of the lead in the water is lead service pipes, house-distribution pipes, or some other lead object used in collecting, storing or delivering the water. Lead is one of the most dangerous inorganic substances with which our drinking water may be contaminated. Lead poisoning from this source is not as common as it was formerly because of the use of corrosion-corrective measures applied to water and because of diminished use of lead pipes.

The various factors that determine the corrosive action of water upon lead are complex. It is not possible to determine in advance whether or not a water will have serious plumbosolvent action. All natural waters have some solvent power. The only sure method of determining to what degree a given water will have corrosive action on lead is by testing the question under practical conditions.

When fresh surfaces of lead are exposed to water, the solution pressure of metal causes it to dissolve, lead ions going into solution and hydrogen ions being precipitated on the metal surface. The action would cease when the water becomes saturated with lead were it not for the fact that the lead ions in solution unite with oxygen with carbon dioxide to form insoluble lead oxide, or carbonate or basic carbonate. Thus, lead ions are removed from solution and corrosion proceeds, although at a slower rate, for the deposited film of oxide or carbonate tends to protect the metallic surface. A proper pH value of the water suppresses the tendency of lead to go into solution by promoting film formation. This is between pH 7.0 and 9.5 according to Baylis. At Providence, Rhode Island, city water drawn through lead



pipes contained about 0.02 part of lead per million parts of water (a small amount) when the pH value was about 8.0; and no lead when the pH value was 9.0.

As a general rule, clean waters have a greater corrosive action upon lead than turbid waters. This is partly for the reason that the silt or organic compounds coat the pipes and protect them mechanically. Acid waters are almost sure to take up lead if allowed to come in contact with that metal. Even so feeble an acid as carbonic acid may under certain circumstances greatly increase the plumbosolvent action of water. Soda water (highly charged with carbon dioxide under pressure) takes up relatively large quantities, if lead pipes are used in soda water fountains or "syphon" bottles. Waters containing carbonates or sulphates are not apt to take up lead because the corresponding salts of lead are insoluble, and thus form a protective coating. Even though a water has no plumbosolvent action, the use of lead piping, lead cooking utensils, lead-lined cisterns, etc., is entirely unjustified for domestic service, for the reason that under certain circumstances electrolytic action, changes in the character of the water, or other causes may lead to lead poisoning.

**ILLUSTRATIVE INSTANCES.** Lead poisoning may occur when a comparatively small surface of lead is exposed to the solvent action of the water (Massachusetts State Board of Health, 1898). This is well illustrated in the following cases:

Case 1. A man about 50 years old contracted lead poisoning from using cistern water. Twelve feet of the distribution pipe were of lead, and almost wholly in the water, as the pipe was bent at right angles and ran across the cistern under the water.

Case 2. In this case the patient was poisoned by cistern water pumped through 10 feet of lead pipe. The symptoms were acute multiple peripheral neuritis, with extensive paralysis. After the lead in the water was removed, recovery was only partial after a period of two years.

**AMOUNT OF LEAD.** The exact amount of lead which may be taken into the system without producing harm is not definitely known. The amount that produces symptoms of poisoning varies with different persons and even in the same person at different times. The continuous use of water containing quantities of lead as small as 0.5 of a part per million has caused serious injury to health. The maximum allowable limit should be 0.1 mg. per liter; this is in accordance with the drinking water standards of the U. S. Public Health Service.

## SPECIFIC DISEASES DUE TO WATER

The principal diseases of man contracted by drinking infected water are typhoid fever, cholera, and bacillary and amebic dysentery. Others, such as schistosomiasis and infectious hepatitis, although less well known, do exist. Water-borne epidemics of these diseases have frequently occurred in the history of the world. It should be remembered that endemic and sporadic cases may also contract their infection through water. The great water-borne tragedies for a time occupied an exaggerated position. They overshadowed the less dramatic, but more insidious, and probably more frequent transmission of infection through other channels. A quantitative estimate of the amount of these diseases spread by means other than water has been realized only in recent years, and since these infections have been eliminated from

water supplies of most large communities, epidemics of typhoid, cholera, and dysentery usually occur independent of water-borne infections.

The general improvement in our water supplies should not lull us into a false sense of security. Eternal vigilance over methods of control for water supplies and water purification must ever be practiced. Laxity invites disaster. A report by Holman and Gorman for the period 1920 to 1936 lists 470 epidemics of water-borne disease in the United States and Canada, of which 33 were in cities of over 10,000 population. For the period 1938-1945 a total of 327 outbreaks of water-borne disease was recorded. Of these, 100 were in public water supplies, three of them in comparatively large cities. It is evident that outbreaks of enteric disease traceable to water are possible, even in larger communities, unless stringent control measures are constantly practiced.

It is worthy of note that almost all the large water-borne outbreaks that have been investigated have been traced to a quick transfer of the infected material from the patient to the victim. In Pittsburgh, the Typhoid Fever Commission showed that most of the fever there had been due to nearby rather than to remote pollution of the river. The greater the distance and the longer the time between the source of the infection and the use of the water, the less are the chances of harm because of nature's purifying agencies.

Typhoid, cholera, and dysentery bacilli are not known to multiply in water under natural conditions. Almost all the great water-borne epidemics of typhoid fever have occurred in the spring, winter, or fall of the year, when the water is cold. Water-borne epidemics of typhoid in the summertime, when the conditions would seem to be favorable for multiplication of the bacilli, are relatively infrequent. The dilution must have been enormous in many of the cases recorded; that is, there must have been very few typhoid bacilli in a tumblerful of water. This illustrates how very few bacteria, when fresh and virulent, may induce disease.

Many large epidemics have been traced to individual instances of pollution. The typhoid epidemics at Butler, Plymouth, New Haven, Nanticoke and Reading, involving 3,929 cases with 361 deaths, were each caused by the careless treatment of the discharges of one individual patient.

The great water-borne epidemics of disease have always been caused by polluted river or lake waters, and not by ground waters. Ground water, however, has been responsible for a larger number of small outbreaks of typhoid fever, especially in limestone districts, as at Lausen, Switzerland; Paris, France, etc. Usually, when well becomes badly infected it is from a nearby privy or sewer, as in the instance of the Broad Street cholera epidemic in London, and the epidemic of typhoid fever at Santa Ana, California.

Public water supplies become contaminated in various ways. The use of a raw water into which is continually discharged the sewage of other towns has occurred at Pittsburgh, Lawrence, Niagara Falls, Albany and Philadelphia. A city may drink the water of a lake which has become its own cesspool, as once did Chicago, Cleveland and Burlington. The pollution may come from the wastes of individual houses, as at Plymouth, or from institutions or factories; or the pollution may come from privies situated directly over the stream or on its banks, as at Ithaca; or the pollution may come indirectly after the offending matter has been deposited on the surface of the ground, later gaining access to the water course by the washing



of rain or seepage through ground seams. In some instances epidemics originate through carelessness in a town that has been supplied with a pure or purified water. Thus a water pipe laid through a polluted pond or stream may become sufficiently disjointed to permit admission of the infected water, as occurred at Baraboo, Wisconsin; Palmerton, Pennsylvania; and Olean, New York. There is a record of numerous epidemics due to mixing in cities having dual water supplies. Epidemics have originated as a result of the unusual drain upon the water supply at times of fire, as in the case of Lawrence; or through failure of valves to operate, as in the case of Wilkesburg, Pennsylvania; when the ordinary water supply was judged to be insufficient and no public warning was given of the substitution as at Newburyport; when a valve in a forgotten cross connection was unintentionally opened, as at Rochester, New York; or when polluted water was furnished temporarily while the filter plant was undergoing repair, as at Lawrence, Massachusetts, in 1902; in Brewer and Poughkeepsie, New York; and in Millinocket, Maine. Various public wells have become infected through ground seams, and have thus caused epidemics of typhoid fever at Trenton, Newport, and Mt. Savage, Maryland. In recent years outbreaks have resulted from the failure of chlorination plants, or other processes used to purify a polluted supply.

In addition to the usual sources of pollution of a surface water, the following, while relatively infrequent, may be particularly dangerous, for the reason that they are apt to take place near the source of supply: discharges from water-closets of railroad trains while crossing bridges or passing the banks of reservoirs and streams; picnic parties; camping parties; construction gangs; fishermen; ferryboats and other craft upon navigable streams. Boats plying lakes may discharge dangerous and obnoxious material very near an intake.

Illustrative water-borne outbreaks are given in Chapter 3, pages 190-197.

**Diarrhea.** Polluted waters not infrequently cause diarrhea, sometimes as widespread epidemics, sometimes as small outbreaks or sporadic cases. Whenever there is a water-borne outbreak of typhoid fever or cholera there are also large numbers of cases of diarrhea and gastro-intestinal disturbances in which the precise etiological factor has not been discovered. Some of these cases may be mild instances of the major disease. Infantile diarrheas are especially prevalent at such times and are very likely due to the contaminated water. Thus, Reincke states that infantile diarrhea was greatly lessened after the improvement in the water supply at Hamburg. The same phenomenon was noted by Hiram O. Mills after the filtration of the water supply of Lawrence, Massachusetts. Sedgwick noted an excessive prevalence of both typhoid fever and diarrhea in Burlington and attributed the diarrhea to the sewage contamination of the water supply. Whipple states that in Albany there was a reduction of 57 per cent in the mortality from diarrheal diseases after the introduction of filtration in 1898. Chapin questions whether such statistical evidence is sufficient to incriminate water as an influence to the causation of diarrheal diseases.

Numerous outbreaks of diarrhea have been attributed to the following microorganisms in water, viz.: *Escherichia coli*, *Salmonella enteritidis* (Gartner), *Pseudomonas aeruginosa*, proteus bacilli, *Clostridium welchii*, *Bacillus mesentericus*, and streptococci. Water containing these and other organisms is not infrequently regarded as the cause of outbreaks of gastro-intestinal irritation. The symptoms vary

ately in intensity, but usually the disease is not fatal except in the young and ble. The relation between the diarrhea and the water is usually based upon the t that the same species of micro-organisms are found both in the water and the stools. Corroborative evidence, such as the finding of specific agglutinins and other antibodies in the blood, lends countenance to the claim that the particular micro-organism is, in fact, the cause of the complaint. The evidence is suggestive but not conclusive.

## THE SANITATION OF SWIMMING POOLS

Although there is little or no positive epidemiological evidence of the transmission of disease from person to person in swimming pools and bathing places, there is a strong suspicion on the part of medical and public health authorities that such transmission does occur. Careful attention to the sanitary condition of public pools and bathing places is, therefore, an essential part of a public health program. The American Public Health Association issues periodic reports on recommended practice for the design and operation of such establishments.

The diseases which are considered to be potential hazards in swimming pools are: inflammatory infections of the upper respiratory tract and conjunctiva; injury and inflammation of the ears; skin diseases; and intestinal infections. Typhoid fever and diarrheal conditions have been traced on inferential evidence to swimming pools. One of the most common infections incurred in bathing establishments is ringworm of the feet, or epidermophytosis, commonly called "athlete's foot." It is not contracted from the pool water, but rather by contact with floors and walks of locker rooms and pool if they are not kept clean and well drained. Towels and swimming suits may be another source of this infection.

The chief danger of infection comes from the water, if not kept clean, or from the towels and swimming suits, if not disinfected. The source of the infection comes in almost all instances from the persons using the pool. Stringent regulations should be in force to prevent use of the pool by persons suffering with skin diseases, swimming ears, ulcers, conjunctivitis, venereal disease, or signs of inflammation of the upper respiratory tract. Full showers, with soap, under inspection, should be demanded of all bathers *before* entering the pool. Especial attention should be given to the perineal region. When water strikes a person's body, the natural tendency is to urinate. For this reason ample toilet facilities should be provided, and they should be so located that exit from them is through the showers and not directly to the pool.

Bathers should be instructed in pool sanitation. Nude bathing should be encouraged, because it favors inspection and does away with the danger of contracting infection from the swimming suit.

The water should have an initial purity equal to that of a safe drinking water and should be kept clean by filtration and safe by disinfection. The best present-day practice for keeping the water of swimming pools in a satisfactory sanitary condition makes use of a combination of treatment, including suction cleaners to remove coarse material that has settled out, such as hair, lint and fibers; refiltration with the continuous or intermittent use of alum to remove finely divided suspended



matter; and, finally, disinfection of pool water with chlorine to destroy pathogenic and other forms of bacteria.

Other germicides have been used for disinfection, notably ozone and ultra-violet light. Their use is not recommended, chiefly because they provide no residual disinfectant in the water to take care of fresh, incoming pollution. The bathers are constantly contributing a bacterial load to the water and the transfer of bacteria from one bather to another may occur in a short period of time. Hence, it is necessary to maintain a residual of disinfectant in the water. The recommendations of the American Public Health Association call for a residual chlorine of 0.4 to 0.6 part per million if chlorine alone is used, or 0.7 to 1.0 part per million if chlorine-ammonia disinfection is employed. Too much chlorine is unpleasant and irritates the eyes and nose. The use of chlorine-ammonia disinfection minimizes the irritation, but the disinfecting action is slower, and, therefore, a higher residual must be carried.

It is important to maintain a proper pH value in the water. Acid conditions irritate delicate mucous surfaces. Recirculation with addition of alum and of chlorine results in a lowered pH value. Experience indicates that a pH of 7.0 to 7.6 causes no complaints on this score. To maintain this value or a higher one, it is necessary in many cases to add soda ash.

In open pools algae sometimes cause troublesome growth in the water or on the bottom and sidewalls. An occasional use of copper sulphate combats these growths.

The disinfection and filtration of the water in the pool is economical, in that it is not necessary to change the water as often as without treatment. Decency and safety require frequent additions of fresh water. If clarification and disinfection are properly conducted, the demands of decency and safety will be met by the daily addition of fresh water in a volume equal to at least 10 per cent of that of the pool. Wherever possible, fresh water should be added continuously.

The examination of swimming-pool water for coliform bacilli has long been the usual method of control. If present, they represent, in most cases, contamination from bathers and indicate potential infection with pathogenic intestinal bacteria. They are not, however, associated with the germs of the eye, ear and respiratory infections, which are more often attributed to swimming-pool contacts. There is need of a better index of pool contamination. In recent years some work has been done on the isolation of streptococcus forms from swimming-pool waters, but the standards recommended by the Joint Committee on Bathing Places of the American Public Health Association and Conference of State Sanitary Engineers (1949) are still based on a 37° C plate count of less than 200 per ml., and the absence of coliform organisms in 50 ml. of water. Attention is called to the value of tests for streptococci, but no standards are recommended.

In localities where blood flukes, *Schistosoma*, occur, special precautions are necessary with respect to bathing places. According to Leiper, the cercariae, which produce the infection by penetrating through the skin, are unable to live in water more than 36 hours after their escape from the snails which act as intermediate hosts. Consequently, he recommends that water before it is used be stored for not less than 36 hours, better 48 hours, in reservoirs that are protected from inva-

n by snails. Copper sulphate and copper carbonate have also been used successfully to eliminate snails.

The sanitation of swimming pools requires good design and construction and efficient management. An average of 27 square feet of pool area should be provided for each swimmer who may be expected to be present at the time of maximum load. The pool should have a smooth lining. When empty, the tank should be scrubbed, flushed and dried. The cleanliness of the tank is aided by the construction of troughs at the edges to afford place for expectoration and to prevent sputum from the floor draining into the pool. Sediment on the bottom should be removed with suction pumps. The filtering should be continuous and the filter of sufficient capacity to refilter all the water in the tank in 8 to 12 hours. It is essential that the water be clear, not only for esthetic reasons, but also in order to reduce the hazard of drowning.

Control of foot diseases incited by fungus infection has become an important function of swimming-pool operators. At some pools the spread of such diseases has been held in check by the practice of maintaining scrupulous cleanliness and good drainage of dressing room floors and pool walks, together with the proper cleaning and disinfection of towels and the exclusion of bathers suffering from these infections. At other pools the following preventive measures have found application:

1. Daily washing of floors, benches and stools with a sodium hypochlorite solution containing 0.3 to 0.6 per cent available chlorine, or with a calcium hypochlorite solution of the same strength.
2. Placing of foot baths between the locker room and showers, the baths containing 0.3 to 0.6 per cent available chlorine or 10 to 15 per cent of sodium thiosulphate. Sodium thiosulphate reduces the available chlorine in the pool, and, therefore, a thiosulphate foot bath should be used only by bathers leaving the pool. Many authorities now doubt the value of foot baths for the prevention of fungus infections, and they are often omitted in modern pools.

Satisfactory hygienic conditions in and around swimming pools require suitable administration of the plant, including the supervision of the working force, the inspection and ablution of the bathers before they enter the water, and their instruction in pool sanitation. Finally, sterilization of the towels and bathing suits by boiling or steaming after each use will avoid one of the means of conveying infection.

## DRINKING FOUNTAINS

The movement toward the abolition of the common drinking cup has led to the development of so-called drinking fountains, of which there are many types on the market. They may be divided into intermittent and continuous, and each in turn into those with and without suitable mouthguards.

The water should not pass through a cup sure to become contaminated. Experiments show that it takes a long time for bacteria to be eliminated from these cups. The design should be such that the user cannot touch the ball with the lips, and that waste water cannot remain to endanger the next user of the fountain. The Committee on Sanitary Drinking Fountains of the American Water Works Association (1918) recommended that: (1) mouthguards are a necessity; (2) the intermittent vertical jet fountain is unqualifiedly condemned; (3) continuous vertical



jet fountains are open to suspicion; and (4) a slanting jet protected with a mouth-guard is perfectly safe.

### ICE

Since many potentially water-borne pathogens are not killed by freezing, ice is a possible vehicle for the transmission of water-borne disease. Although few well-authenticated instances of such transmission can be found, the extensive use of iced drinks in this country requires that attention be given to the sanitary quality of ice.

Sedgwick and Winslow (1902) made quantitative studies on the effect of freezing upon cultures of the typhoid bacillus and showed that 50 per cent of the organisms die at the end of the first week, 90 per cent at the end of the second week, and practically all at the end of 12 weeks. They considered that in nature the destruction might exceed rather than fall short of these figures, for the experiments were made in a test tube where all the bacteria are incorporated in the ice, while in nature many are extruded during the process of freezing.

As water crystallizes it extrudes suspended matter and even dissolved substances. The extent to which water thus purifies itself depends, however, upon conditions, for under certain circumstances the impurities may become entangled or even concentrated during the process of freezing.

Both natural ice and manufactured ice present sanitary hazards.

**Natural Ice.** Natural ice should be harvested from water of good sanitary quality and handled in a cleanly manner. It is not unreasonable to demand that the water from which the ice is harvested meet the U. S. Public Health Service drinking water standards. Under natural conditions the surface layer of ice contains most of the impurities and the lower layers are relatively purer, for the reason that ice grows from above downward and extrudes both suspended and dissolved matters; the surface also receives additional contamination from the dust, snow, flooding, and other sources. It is, therefore, good practice to plane the surface of snow ice.

The fact that natural ice is usually purer than the water from which it is taken is shown by the analyses in Table 40-1 which give the chemical and bacterial composition of natural ice and the water from which it was frozen. Only the minimum and maximum values for each set of samples are given. In this case the water was a sewage-polluted stream.

The reduction in the number of bacteria is noteworthy. It is unwise, however, to rely on this natural purification to produce safe ice from polluted water. Another source of contamination lies in improper handling of the ice after harvesting.

**Manufactured Ice.** Manufactured ice is made by the ammonia process. The condensed ammonia in expanding requires heat which it takes from surrounding objects and in this way the water is frozen. The freezing takes place in rectangular cans, the water freezes from the sides of the can toward the center, and the impurities are extruded and concentrated in the core, which is often visible in a cake of can ice. In well-equipped plants this visible core of concentrated impurities is removed by suction apparatus before it freezes, and clean water is substituted. During the freezing process, air is bubbled through the water, in order to facilitate the collection of the impurities in the core, and thus to produce a clear cake.

Table 40-1. Chemical and bacterial composition of natural ice and the water from which it was frozen

	Ice 3 to 6 Inches Thick		Water	
Number of samples	6		6	
Free ammonia	.008	— .034	.046	— .084
Ureminoid ammonia	.156	— .214	.146	— .276
Strates	.05	— .20	.35	— .48
Chloride	2.0	— 3.0	4.5	— 6.0
Hardness	11.0	— 28.5	57.0	— 61.5
Bacteria per ml.	30	— 210	5,200	— 13,000
Coliform group present in	10 ml.	— 10 ml.	1.0 ml.	— 0.1 ml.
Number of samples	7		4	
Free ammonia	.016	— .136	.006	— .038
Ureminoid ammonia	.230	— .726	.116	— .166
Strates	.0	— .050	.260	— .400
Chloride	.8	— 3.5	5.5	—
Hardness	18.0	— 34.0	58.5	— 62.0
Bacteria per ml.	2	— 60	2,500	— 3,900
Coliform group present in	absent		1.0 ml.	— 0.1 ml.

The chemical figures in this table are in parts per million.

Manufactured ice is usually made from water of good sanitary quality, since good ice cannot be produced from contaminated water. The water is often distilled before use. Manufactured ice made from water of good quality is completely safe properly handled and stored after freezing. However, it may become contaminated if the workers are careless. In one case, six specimens of ice made from water containing 64 bacteria per ml. and no coliform organisms gave the results shown in Table 40-2.

Table 40-2. Analysis of six specimens of ice made from water containing bacteria

Number of Sample	Manufacturer	Organisms per ml. (Plate Count)	Coliform Organisms
24	C. P. Co.	455	Absent
29	C. P. Co.	5,000	In 1 ml.
26	G. Ice Co.	230	In 10 ml.
27	G. Ice Co.	650	Absent
32	G. S. Co.	470	Absent
34	P. Ice Co.	8	In 1 ml.

Contamination may be transferred from the shoes of the workers to floors, tanks and cans; it may also come from handling of the cakes, from contaminated crushing machines and from numerous other sources.

The widespread use of ice in iced drinks and in contact with foods makes it necessary to demand that ice be handled under the same conditions of cleanliness that are expected in the handling of other foods.

**Ice and Disease.** A search of the literature discloses but few instances of disease attributable to impurities in ice. While the experimental evidence indicates that there is a quantitative reduction of the number of bacteria in freezing, and that the imprisoned bacteria gradually die, nevertheless, experience has shown that low



temperatures alone cannot be depended upon to remove the danger of typhoid infection. In only a few isolated instances, however, has ice itself been accused of being the vehicle by which the infection of typhoid fever has been spread.

Hutchings and Wheeler (1903) report an epidemic of typhoid fever in the St. Lawrence State Hospital, three miles below Ogdensburg, New York, which seems to have been due to impure ice. The disease was endemic in the hospital for 10 years, increasing from two cases with the opening of the hospital in 1890 to 40 cases in 1900. Although the water supply, tested bacteriologically and chemically, gave negative results, all observers agreed that the disease was water-borne. In December, 1900, the source of the water supply was changed to the Oswegatchie River, a small Adirondack stream supplying Ogdensburg. This practically put a stop to the disease, for there were no cases of typhoid that were not clearly contracted elsewhere until October, 1902.

Following this eight persons were attacked, seven of whom were employees in the dining room. It seems the milk "could not have been infected." The water was excluded and other sources studied, with negative results. The ice fell under suspicion. It had recently been taken from a newly opened ice-house. The ice had been harvested from the St. Lawrence River at about the same spot as the ice previously used. It was gathered in February and consequently had been stored for seven months. This ice yielded a count of 30,400 bacteria per ml. on agar plates and 50,400 on gelatin. Of eight fermentation tubes three showed the presence of coliform bacilli.

The stock of ice was then examined. In the center of certain cakes were found foreign substances in the form of black or dark brown granular matter. Examined under the microscope, this matter was found to be teeming with bacteria, from which both coliform and typhoid bacilli were isolated in pure culture.

With the discontinuance of the use of this infected ice the epidemic gradually subsided. There were in all 39 cases. The evidence of this outbreak was studied by Hill, who doubted the relation of the ice. The disease resembled a carrier outbreak.

Despite the rarity of specific, well-established outbreaks due to contaminated ice, there is little doubt that impure or improperly handled ice may be responsible for many individual cases of illness. The decline in the use of natural ice, and the improvement in the quality of water supplies from which manufactured ice is made, have reduced the chance of direct contamination of ice. The dispensing of crushed ice for iced drinks still leaves much to be desired. Studies made in the dining halls of Harvard University have shown that unless great care is used in dispensing, the crushed ice will show the presence of coliform organisms, presumably from the hands of dispensing employees. It is necessary to emphasize the fact that ice is a food, and should be handled as such.

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# 41

## SEWAGE

GORDON M. FAIR, M.S., DR.ING.

The water-carried discharges of the human body together with the liquid wastes from household and factory are called sewage. The discharges themselves consist chiefly of feces and urine, but they include also washings and secretions from the skin, mouth, and nose. Savage tribes and nomadic races may move away from their excreta, but civilization requires that the wastes of the human body be removed from habitations promptly and safely, and that they be disposed of in like manner. In rural communities excreta are generally cared for in privies; in urban communities they are usually removed by means of the water-carriage system of sewerage.

Three types of considerations govern the disposal of human excreta: hygienic, esthetic, and economic. *Hygienic* considerations are concerned chiefly with the fate of pathogenic organisms that may be contained in human wastes. The microorganisms of typhoid fever, cholera, the dysenteries, hookworm, and other intestinal worm diseases, as well as infectious hepatitis and certain other intestinal viruses, have their ultimate source in the alvine discharges of man and are conveyed from host to host through many channels: by water, food, soil, or contact; sometimes by human agencies, sometimes by animals, often by flies. Since the wastes from household and industry must be disposed of ultimately on the land or in water, the safe disposal of human excreta requires that the methods chosen shall eliminate or at least minimize dangers to the following:

1. Private and public water supplies obtained from surface or underground sources.
2. Natural ice supplies taken from lakes or ponds.
3. Shellfish layings and other useful aquatic life.
4. Bathing beaches on fresh or salt water.
5. The soil.
6. Food substances that are to be consumed raw.
7. The water supply of domestic animals.

Some consideration must be given also to the prevention of nuisances that affect the public health and comfort. Decomposing sewage matters may release objectionable odors and noxious gases, and recreational facilities may be impaired by improper disposal of human wastes.

The *esthetic* considerations of sewage disposal deal with the destruction of the

organic matter contained in excreta and the avoidance of offensive conditions. They demand that excreta be cared for in such manner that they will become neither unsightly nor objectionable to the sense of smell. They are also concerned with providing privacy during urination and defecation.

The *economic* considerations are concerned chiefly with the price that must be paid to secure the requirements of hygiene and esthetics, and with the possible damage to industrial water supplies, livestock, fish and other useful aquatic life, riparian properties, river and harbor improvements, and navigation. In western countries they do not deal as much as in the East with the utilization of excreta for fertilizing purposes.

## THE RURAL PROBLEM OF SEWAGE DISPOSAL

One of the most difficult problems of modern sanitation is to provide proper disposal of fecal matter for rural communities, summer hotels, temporary camps of laborers, summer colonies at beach and mountain, and individual houses in villages and on the farm. It is difficult because the necessary structures, although small and simple, are often thoughtlessly constructed; because adequate care of the processes is more or less disagreeable and therefore neglected; because the inherent dangers are not understood or appreciated; because the economic status of many rural sections is so low that the construction of satisfactory privies is often too great a financial burden; and, finally, because collective sanitation is more difficult of administration in areas of scattered dwellings than in urban communities.

**Privies.** There are still large areas of the United States in which no attempt is made at the sanitary disposal of human excreta. A clump of bushes or trees satisfies the urge for privacy during defecation, and excreta are scattered on the surface of the ground in disregard of the Mosaic law of burial (Deuteronomy 23:12, 13).

A first step towards sanitation is found in the *latrine* or straddle trench often used in temporary camps. This consists of a relatively shallow trench which the user straddles. A layer of earth is placed daily upon the fecal matter, and the trench is back-filled when camp is broken. Seating facilities are sometimes provided by a supporting pole or rough box seat. This type of trench has its corollary in rural life in the so-called "umbrella type" of privy, consisting of a box placed over a hole in the ground. It is not a privy in the true sense of the word, since it affords no privacy to its user, neither does it protect him against the elements.

**SURFACE PRIVIES.** The surface privy (Fig. 41-1) provides privacy but little else. The excreta accumulate on top of the ground, the liquids leach away or evaporate. Many surface privies are flimsy, malodorous structures with inadequate foundation, with cracks between boards, without screening, with ill-fitting doors, and open at the back so that flies and animals have access to the excreta or so that the privy contents are scattered upon the ground. Such privies are an abomination.

**PIT PRIVIES.** Of proved sanitary value are privies in which the excreta fall into pits in the ground. The pits may be shallow or deep and built so that their contents leach away, or they may consist of tight vaults. The use of pits prevents pollution of the soil, tends to reduce the fly menace, and keeps odors down. Flies shun dark places. The deeper the pit the fewer the flies, especially if the contents are



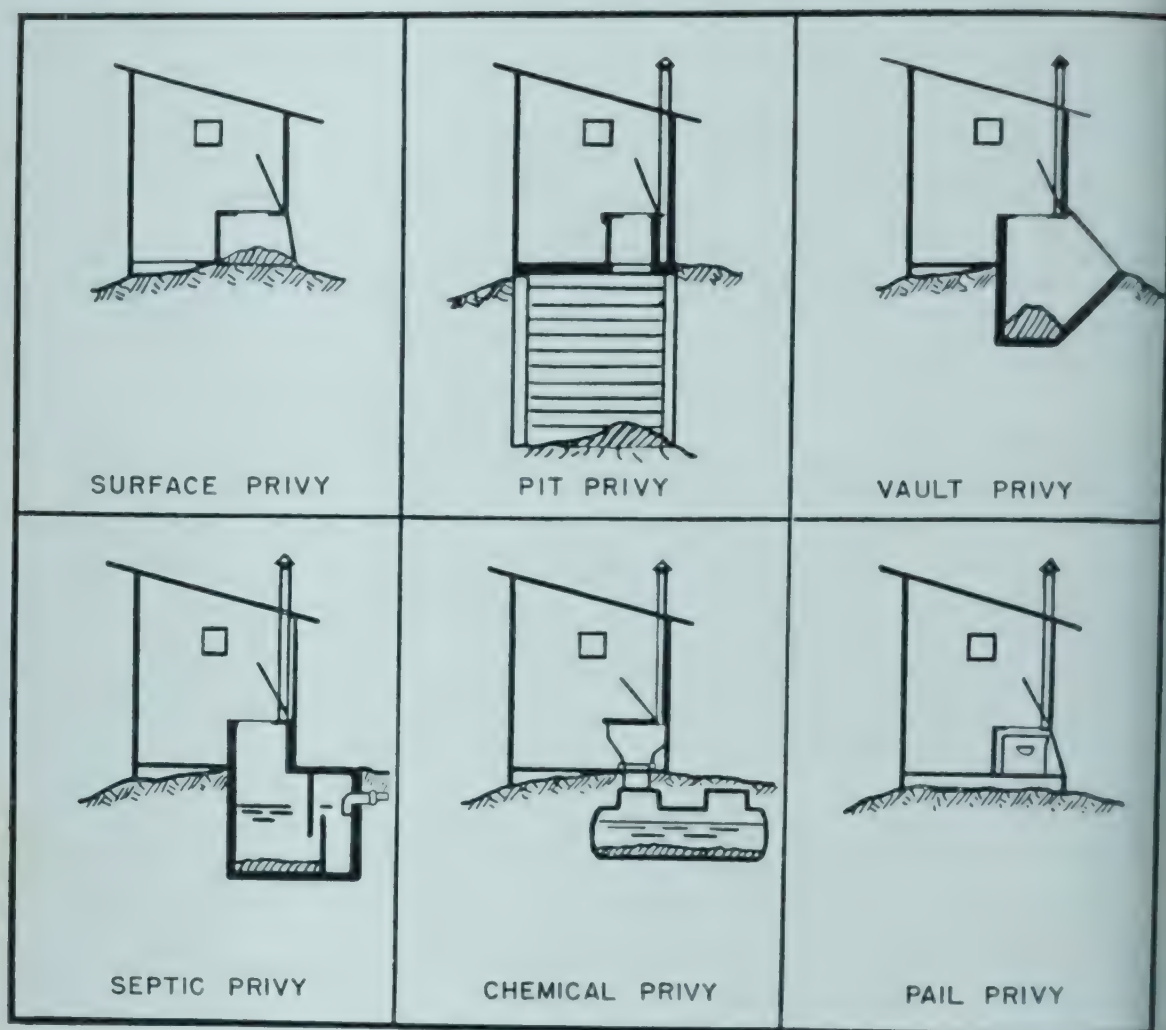


Fig. 41-1. Types of privies.

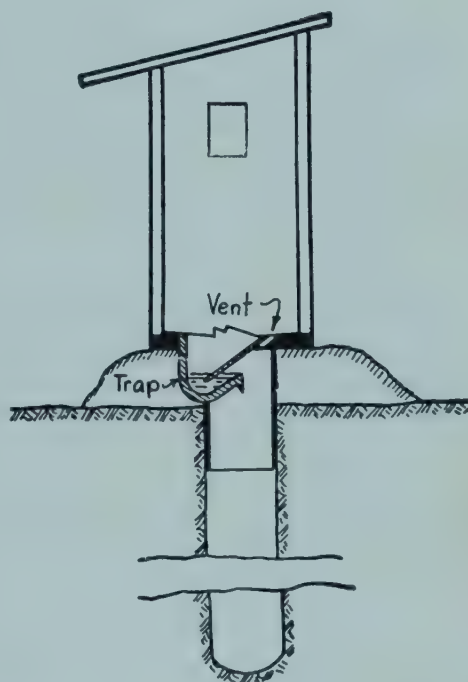
covered with sand, soil, sawdust or some other absorbent material. If the pit is well constructed and covered by a concrete slab to which a riser of cast iron or concrete is firmly attached and if the seat is made self-closing, little attention need be given to the tightness and screening of the superstructure. Such a pit becomes an independent sanitary unit. The superstructure merely provides privacy and protection. A ventilator rising through the privy roof or terminating in a screened opening near the top of the seat reduces odor and keeps moisture from condensing on the bottom of the privy seat.

Deep pits are a greater menace to neighboring wells than shallow pits, because they are nearer the ground-water table. Such pits become objectionable in places where the soil water rises into them.

No arbitrary rules as to the minimum distance of a privy from a well can be laid down, as everything depends upon the character of the soil, the slope of the ground, the elevation of the natural ground water, and the draught of water from the well. A distance of at least 25 feet is indicated in sandy soil and preferably 50 feet or more. In clay soils that dry and crack and in limestone regions that contain crevices in the rock, leaching privies should not be used. Wells may then be polluted a mile or more away. The pollution of ground water is prevented by

water-tight privy vaults made of brick or concrete. Frequent cleaning is then necessary. For use in rural schools, in particular, vault privies are often constructed with two or more receiving compartments and seats. After one vault has been in service for a time the seat above it is battened down and another vault is called into service. This gives the organic matter in the unused vault time to decompose and thereby reduces the disagreeableness of vault cleaning.

**BORED-HOLE PRIVIES.** In the Orient the bored-hole privy or latrine is favored by health officials. As shown in Figure 41-2, the most important feature of this latrine is a bored hole 10 to 24 inches in diameter sunk to a depth of 12 to 26 feet and preferably penetrating the ground-water table. In silting soil the sides are revetted by a cylinder of bamboo, wire netting, or sheet metal. Since the squatting method of defecation prevails in the Orient, the superstructure commonly consists of a floor slab often provided with foot rests adjacent to a more or less rectangular hole through which the excreta fall into the latrine. A water trap may be installed where the ground-water table rises within a few feet of the ground surface and furnishes a breeding place for insects or renders the privy malodorous. A privy house or more primitive shelter completes the bored-hole latrine. The danger of contaminating ground-water supplies must be clearly recognized.



After Yeager.

Fig. 41-2. Bored hole latrine.

**SEPTIC TANK PRIVIES.** These are said to have originated in India where they have been used from time immemorial. The excreta fall into water, where saprophytes, principally bacteria, decompose much of the organic matter, part of it being liquefied or gasified. The tanks are water-tight, but an outlet pipe into the ground is usually provided near the top of the last compartment. Through this pipe the overflowing liquid passes into the soil. Overflow, together with decomposition and evaporation, prevents the accumulation of water. In some climates, it may be necessary to add water periodically. In warm climates, tank privies are decidedly superior to the older methods, but they are relatively expensive and are not well adapted to the severe weather of the North. The so-called Kentucky privy is made of concrete, but large tile pipe can also be used to create a water-tight chamber.

**CHEMICAL TANKS.** These are water-tight compartments, usually made of sheet metal, filled with water in which caustic soda or a similar chemical is dissolved. The organic matter is decomposed chemically instead of biologically, and microorganisms are largely destroyed. The method is safe but relatively expensive. The chemical has to be renewed at intervals and its cost is likely to induce householders to use too little. The process then breaks down. Means must be provided for disposal of the spent liquor.



**PAIL PRIVIES.** In villages and even in some large-sized communities the so-called pail system, or scavenger system, is sometimes used. Pails placed beneath the privy seat are removed and emptied at intervals by a collector. Earth, ashes, sawdust, or some other absorptive material are put into the pails to suppress odors. The system is often a failure, due to neglect, the difficulties of final disposal, and the cost of maintenance and upkeep. Unless well supervised, such a system, starting off satisfactorily, is likely to degenerate until, after a few years, conditions become dangerous.

**DROP PRIVIES.** Privies have sometimes been built to overhang brooks or rivers. The fecal matter drops into the water and is carried away by the stream. Although this is an approach to the water-carriage system for removing human wastes, such practice cannot be used indiscriminately. Typhoid fever epidemics have been traced to drop privies situated on tributaries of streams used for municipal water supplies. Most states, therefore, do not countenance the building of these structures.

**Disposal of Privy Contents.** No matter what type of privy is employed, it becomes necessary sooner or later to remove part or all of the contents of the receiving chamber. This is especially true of pail privies. Here the pails must be removed at frequent intervals, usually once a week. Vault privies require less frequent cleaning, particularly when the liquid wastes are permitted to leach away through the ground. A semi-annual removal of the accumulated solids usually suffices. Pit privies are sometimes cleaned but, more commonly, the superstructure is moved over a new pit when the old one is nearly full. The old pit is then covered with earth. Septic tank privies are pumped out only at rare intervals, because much of the solid material gasifies or liquefies, the liquid passing into the ground through the overflow which may attach to subsurface tile drains. Chemical tanks, too, are only rarely emptied. A cesspool is sometimes provided to receive the tank contents which are emptied into it from time to time. The chemical tank is then refilled with caustic solution.

Apart from the use of night soil, or privy contents, for fertilizing the fields, other methods for their ultimate disposal are: burial and composting, incineration, and disposal in streams or sewerage systems.

**FERTILIZING.** Human excreta, like animal manure, contain materials of fertilizing value. Urine is particularly rich in nitrogen and phosphoric acid. In primitive civilizations human excreta are commonly used to fertilize fields upon which agricultural products are raised. From the hygienic standpoint this practice is to be condemned. Storms may wash the fecal matter into streams, the soil may become polluted, vegetables that are to be consumed raw may become contaminated, and flies may swarm from the fields to human habitations. The fresher the excreta the greater the danger. When the excreta are well rotted and plowed under and when they are not used for crops that are to be consumed raw in the immediate future, the sanitary hazard is reduced.

**BURIAL.** A safer method of excreta disposal is to bury it in trenches or pits, a layer of earth sufficient in depth to prevent escape of hookworm larvae and access of flies or other animals being placed over the material. Sometimes the pits or trenches are oiled, sometimes they are filled with straw or other combustible material which is burned and forms a carbonized crust upon the surface of the wastes.

reduction of the organic matter is slow, and relatively large disposal areas are required. The excreta can conveniently be mixed with other organic refuse, such as garbage, and composted. Pasteurizing temperatures are then reached as in the "sanitary fill" method of refuse disposal (see Chapter 42).

**INCINERATION.** In some of the larger unsewered communities, excreta, more particularly those collected from pail privies, are destroyed by incineration, the liquids being evaporated, the solids passing into the combustion chamber of the incinerator. Small incinerators have been used for this purpose in army cantonments and construction camps. They afford an opportunity for the simultaneous destruction of garbage and rubbish.

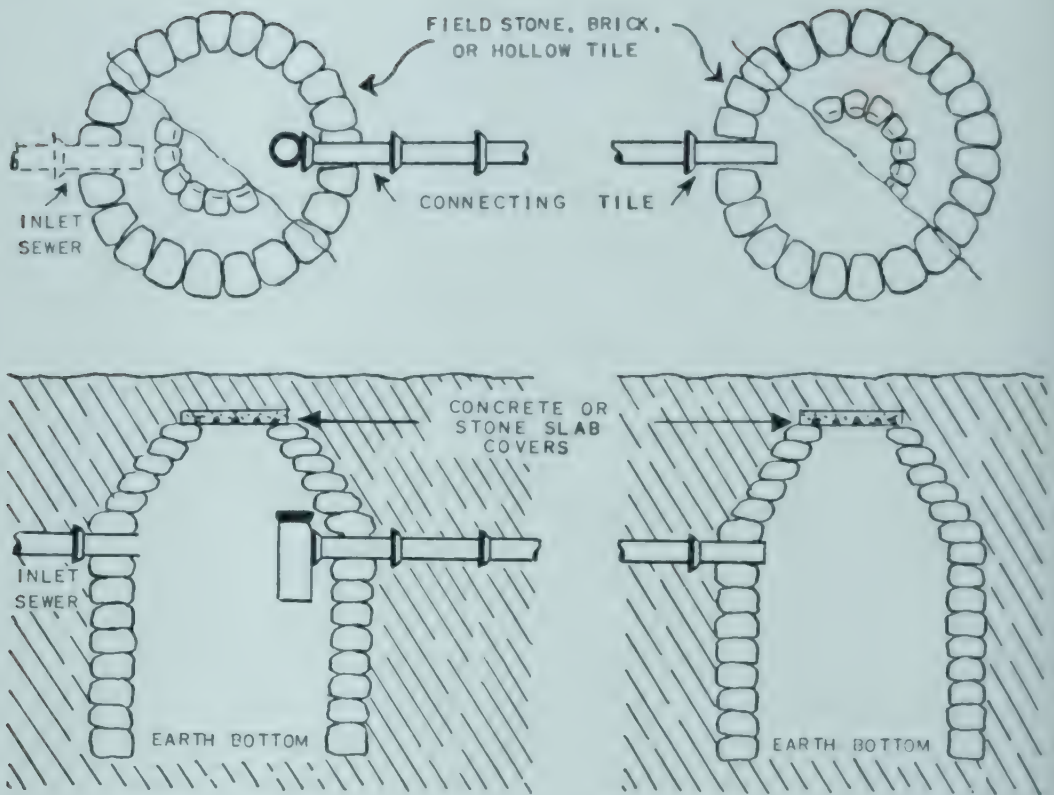
**DISPOSAL IN STREAMS AND SEWERAGE SYSTEMS.** Communities situated near large rivers that do not serve as water supplies for nearby towns may dispose of the collected excreta in central disposal stations in which a jet of water washes the pail contents into a sewer discharging into the river. In communities that contain sewered as well as unsewered areas, the contents of pail privies in the unsewered districts are usually emptied into one of the trunk sewers of the city.

**Disposal of Water-Closet Wastes.** More and more people who live on farms or in small villages are introducing running water into their houses. The electrical distribution of power, gasoline engines, water rams, windmills, and other sources of power have made this possible. Farm plumbing is rapidly increasing and the indoor water-closet is being substituted for the outdoor privy. Whereas this is a sanitary advance, it brings with it new problems that must be solved if healthful conditions are to prevail. Water-closets and other plumbing fixtures greatly increase water consumption, and new means must be provided for getting rid of the increased volumes of waste water. This usually entails the construction of a cesspool, a septic tank, or some other small sewage disposal unit.

**CESSPOOLS.** A cesspool is a pit into which waste water flows. If the pit has impermeable sides or a permeable bottom, it is called a *leaching cesspool*; if water-tight, it is called a *tight cesspool*. Cesspools are generally covered (see Fig. 41-3). Usually the sewage remains in them for a considerable time so that the bacteria and other micro-organisms have ample opportunity to utilize the organic matter for energy and growth. The saprophytes ordinarily found in water require oxygen for their life processes, and fresh sewage from a house usually contains some of it in solution. On reaching a cesspool the saprophytes multiply to enormous numbers and quickly exhaust the available oxygen. The liquid then becomes "anaerobic" or septic. Some micro-organisms can, under these conditions, get the oxygen they need from the organic matter—that is, from the feces and urine, and even from the cellulose of paper. In doing so, they break down the organic matter, and some of the solids are changed to liquids or gases. This *process of digestion* reduces the accumulation of solids in cesspools and prevents the necessity of frequent cleaning.

Cesspools often receive not only fecal matter but also other domestic wastes. When the soil is sandy there is no objection to the use of leaching cesspools; in fact, this method is like that of subsurface irrigation described later in this section, except that the sewage is discharged into the soil below the depth where bacteria are most effectively at work. This may be an important difference, however, as the modification of the dissolved organic matter proceeds by a slower process. Leaching





From N. Y. State Dept. of Health Bulletin 26.

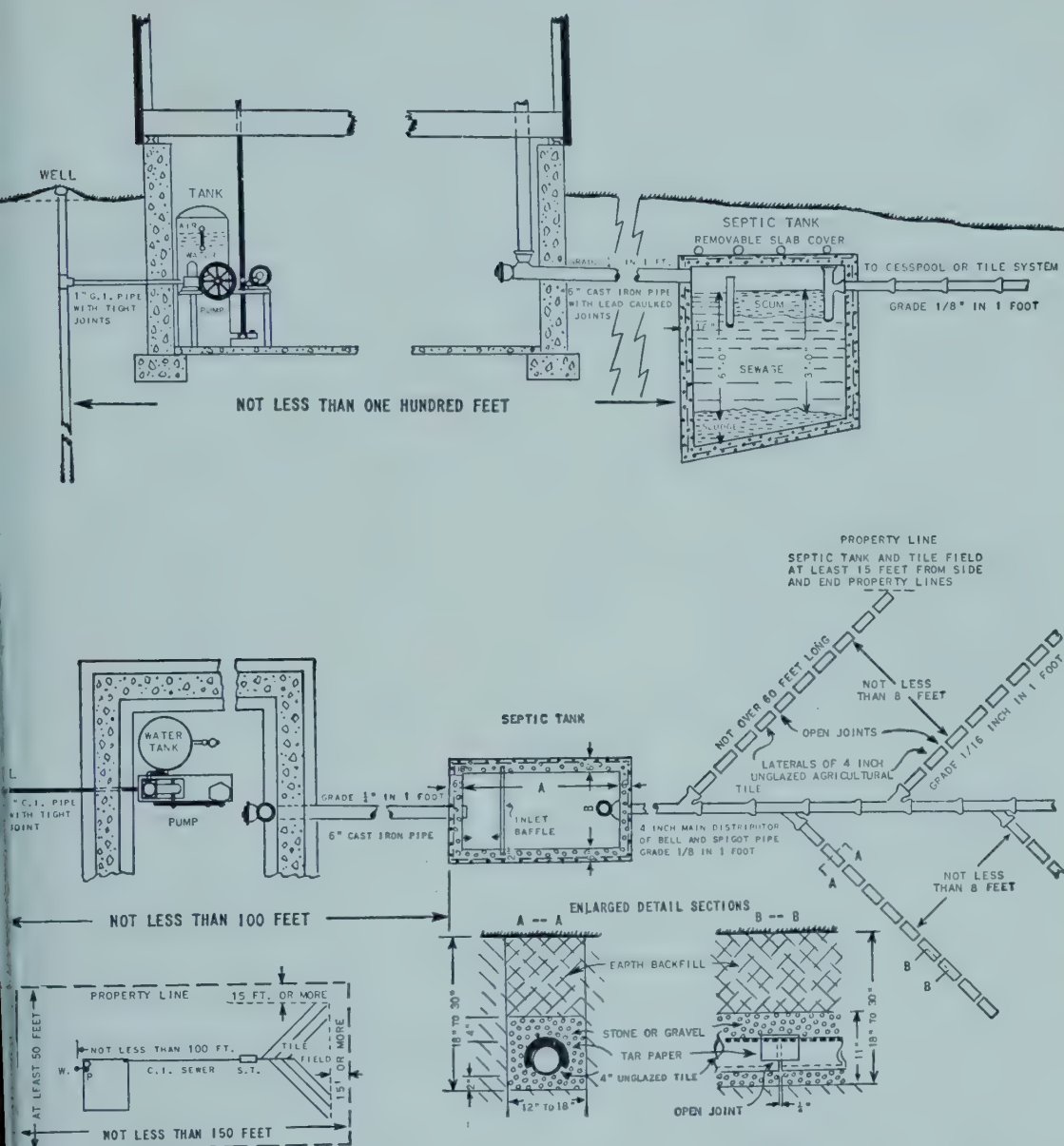
Fig. 41-3. Typical leaching cesspool construction.

cesspools should not be placed near wells used for drinking-water supplies. In sandy soils the danger of bacterial contamination is small if sufficient distance intervenes but, even so, the idea of seepage of sewage into a well is repugnant, and the water may often be tainted by disagreeable odors, even though analyses may show that it is bacterially safe.

Ordinarily, leaching cesspools should not be used in clay soils or in limestone. If they are to be constructed in such formations, they should be made water-tight. They then approximate septic tanks, the effluent being taken care of by subsurface irrigation or some form of land treatment.

**SEPTIC TANKS.** Septic tanks differ from cesspools in having water-tight sides and bottoms, in having a definite outlet as well as an inlet, in having a more or less constant flow of liquid through the tank, and in being advantageously subdivided into compartments. When subdivided, the last compartment commonly serves as a dosing chamber for the irrigation plant or filter. The biological action is the same as in a cesspool. There is liquefaction and gasification of a part of the organic matter, a small amount of more or less stable sludge gradually accumulating at the bottom, a considerable amount of scum being lifted to the top by the entrained gases. The surface scum dries, and its decomposition is retarded.

As for cesspools, the water from septic tanks has to go somewhere. It may be distributed underground by a system of subsurface drains—a good way if the soil is porous—or it may be applied to some sort of sewage filter. A satisfactory construction of a septic tank is shown in Figure 41-4.



From N. Y. State Dept. of Health Bulletin 26.

Fig. 41-4. Typical layout and details of driven well, pressure water system, and sewage disposal plant.

**Other Methods of Rural Sewage Disposal.** Although the cesspool and septic tank constitute the chief devices for the disposal of sewage from small isolated dwellings with water supply systems, a number of other processes can be employed under conditions of soil, location, or volume of sewage to be treated render cesspools and septic tanks unsatisfactory. These methods are much like those used in treatment of sewage from urban communities.

**Disposal of Kitchen and Other Liquid Wastes.** Where privies are used, sink wastes are often put upon the open ground. This may be unsightly, but the danger to health is not great. When plumbing is introduced, the natural thing for plumbers to do is to unite all the waste pipes as they do in cities. This brings wastes from the kitchen and bathroom and fecal wastes from water-closets together and causes



some difficulties because soap curds and grease form a heavy scum and choke the pores of the soil. The grease content of kitchen wastes can be reduced in grease traps. These are tank-like containers in which the grease rises to the surface as the liquid is cooled. The captured grease must be skimmed off from time to time.

**Camp Sanitation.** The disposal of human wastes from camps—that is, from temporary shelters—presents a number of sanitary features not encountered under ordinary urban or rural conditions. The methods of excreta disposal that should be employed are similar to the rural methods that have already been described. Some of the practices of armies on the march or in temporary encampment are applicable to all camps.

**Straddle Trenches.** These consist of relatively shallow trenches which the user straddles. A layer of earth is placed daily upon the fecal matter, and the trench is finally back filled and marked when camp is broken. The shallow straddle trench is recommended only for camps of one night. It is easily and quickly made, and by reason of its slight depth (commonly less than two feet) permits rapid disintegration of the excreta. When trenches of this type are to be used for a longer period of time, they are made deeper and are then called straddle pits. These are sometimes provided with covers. Straddle trenches can be adapted to other temporary encampments as well as to military ones.

**Latrines.** When the camp site is to be occupied for several days or weeks, more permanent facilities must be provided. These commonly take the form of latrines. Pit latrines differ from the straddle trench or pit in being wider and deeper and in providing seating facilities. Latrines are screened from view by brush or by canvas stretched between upright poles. Excreta should be covered with earth, and the trench should be burned out daily with straw and kerosene. When the contents reach to within three feet of the surface, the latrine should be filled, covered with oil and sacking, earthed over, and the site marked. Even when carefully operated, open pits permit the access of flies to the excreta. For this reason, deep-trench latrines may be equipped with self-closing seats that cover the trench tightly. Seats are arranged in single or double rows. The latrine is housed or otherwise screened. A urinal trough draining into the pit or into a separate soakage pit is sometimes provided against one wall of the latrine shelter. Treatment of the pit contents is the same as for the open latrine. Accommodations should be provided to care for about 5 per cent of the personnel at one time.

**URINALS.** Military camps are commonly equipped with galvanized iron cans which are placed in the camp streets at night. These are emptied into soakage pits in the morning and thoroughly cleaned. The ground where the cans stand is burned over each day. Urine soakage pits are sometimes used instead of cans. The pits are filled with stone and covered with sand supported on burlap. Metal funnels carry the urine into the pit from which it leaches into the ground. A pit four feet cube will serve from 200 to 500 men.

**Hygienic Results of Rural Sanitation.** The introduction of sanitary privies is commonly accompanied by other sanitary measures such as the improvement of water supply, the pasteurization of milk, and the screening of houses. The resulting reduction in intestinal diseases, therefore, generally reflects an overall rather than a specific sanitary effect. This fact must be kept in mind in evaluating data such as the following. Typhoid fever deaths in Richmond, Virginia (Harden

ergh, 1924), were reduced from 57 in 1908 to 28 in 1909 following the installation of sanitary privies in all unsewered homes. In Yakima County, Washington, the prevalence of typhoid fever was reduced by about 90 per cent after a campaign for more adequate sanitation. The introduction of sanitary privies in Birmingham, Alabama (Lumsden, 1918), decreased the typhoid fever death rate of 65.5 per 100,000 in 1917 to 17.8 in 1919; deaths from diarrhea and enteritis among children under two years of age dropping 50 per cent during the same period. In North Carolina (Smillie, 1948), sanitary activities reduced the typhoid mortality from 5.8 in 1914 to 0.5 in 1943. Experience has shown, furthermore, that hookworm can be stamped out by the provision and use of sanitary privies and that the incidence of other intestinal diseases can be materially reduced.

## THE URBAN PROBLEM OF SEWAGE DISPOSAL

Although small urban communities can dispose of water-carried household wastes, or sewage, by the methods just outlined, the natural tendency of community sanitation is away from the individualistic methods of the rural householder towards collective sanitation of a more effective nature. The urban problem of sewage disposal naturally falls into two parts: the collection of sewage by what is called the sewerage system, and the disposal of the sewage with or without treatment.

### SEWERAGE

So accustomed are we to present-day methods of urban sewerage that it is hard to realize that the system of water carriage of fecal matter is little more than a century old. The great sewers of antiquity unearthed at Babylon and Nineveh or, the *cloaca maxima* of Rome, still performing service, were built to carry away storm water and underground drainage; not to remove fecal and other wastes from the populations they served. Up to 1815 the public drains of London were not permitted to receive excreta; in Boston fecal matter was rigidly excluded from the sewers until 1833; and in Paris this was so even up to 1880.

Following the report of the Health of Towns Commission in England in 1844, water-closets were rapidly introduced. In 1847 their connection with the sewers was required by law, and the use of cesspools in towns was prohibited. In the United States, Chesbrough designed a general sewerage system in Chicago in 1855; Boston's first sewerage commission was appointed in 1875, but Baltimore was without a sewerage system well into the twentieth century.

The introduction of the water-carriage system accomplished its purpose of getting away with the offensive accumulations of filth around city dwellings, but it gave rise to a series of other problems that sanitarians had to solve. The first sewers, like the ground and storm water drains from which they evolved or after which they were patterned, were naturally built to discharge their contents into the nearest available body of water—into river, lake, or harbor, according to the location of the city. Where the receiving bodies of water were relatively large, no nuisance was caused by doing this; but where they were not, foul conditions were soon manifested. Water supplies also became infected, and in some instances great epidemics followed. Infection was spread in other ways, too, such as the pollution of shellfish layings and of beds of watercress. Thus the problem of the removal of



fecal matter was sometimes solved at one place only to reappear elsewhere. Litigation often arose between riparian owners along the water courses, involving damages caused by the pollution of the water.

**Plumbing Systems.** The house plumbing is the end of the water supply system and the beginning of the town drainage system. On the water supply side, the plumbing system carries water to toilet, washbowl, bathtub, kitchen sink, laundry tray, and other fixtures; on the drainage side, it collects the spent water from these fixtures and discharges them into the public sewers.

**DRAINAGE.** The main features of the house drainage system are one or more vertical *drainage stacks* and the *house drain*. The stacks rise from cellar to roof and collect the wastes from plumbing fixtures. The house drain runs horizontally under the cellar and receives the discharge from the drainage stack, conveying it to the *house sewer*. The latter extends outside of the building to the street sewer or house disposal plant. Pipes carrying the discharge of water-closets or urinals are known as *soil pipes*; those receiving the discharge of any fixture, except water-closets or urinals, are called *waste pipes*. Correspondingly, there are also *soil stacks* and *waste stacks*.

Each fixture is equipped with a *trap* containing a water seal which prevents the passage of air from the drainage system through the fixture into the house. This air is usually malodorous. It may also contain toxic and inflammable gases, such as hydrogen sulphide and the constituents of illuminating gas that has seeped from gas mains into neighboring sewers. In order to prevent the unsealing of traps by aspiration or back pressure as a result of water rushing through them or past

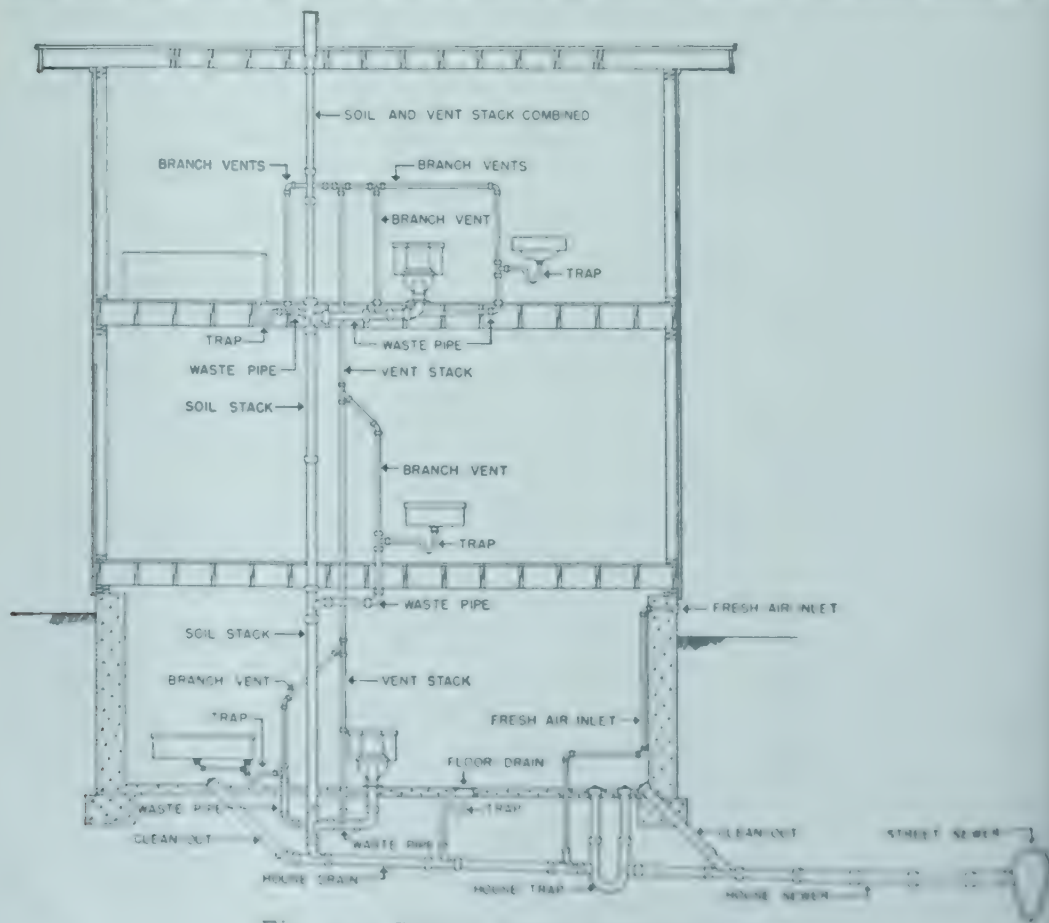


Fig. 41-5. Typical house plumbing system.

em, they are commonly provided with *vent pipes* which carry air into or out of the house drainage system, and thereby relieve unwanted vacuum or pressure conditions. Vent pipes from individual fixtures unite in a *vent stack* which rises vertically through the building from the lowest to the highest fixture. The vent stack parallels the soil or waste stack that it serves and is commonly connected with the drainage stack above the highest fixture. The combined stack passes through the roof into the atmosphere. A typical house plumbing system is illustrated in figure 41-5. A house trap can be installed to seal the entire house drainage system against the air in the street sewer but is commonly omitted, except in cold climates, where cold air entering the sewer through the many house vents might result in frozen sewers, and in houses on steep side-hill locations, where air from the vent pipe of a lower-lying house may be wafted into the living quarters of an upslope neighbor. The plumbing system should be pneumatically tight as well as tight against leakage of waste liquors and egress of cockroaches and other vermin.

**WATER SUPPLY.** The water supply pipes of homes, hospitals, offices and other buildings should convey water to fixtures in such fashion that there is no possibility of waste water being sucked or forced back into the water supply system and polluting or contaminating the water supply. The opportunity for backflow exists

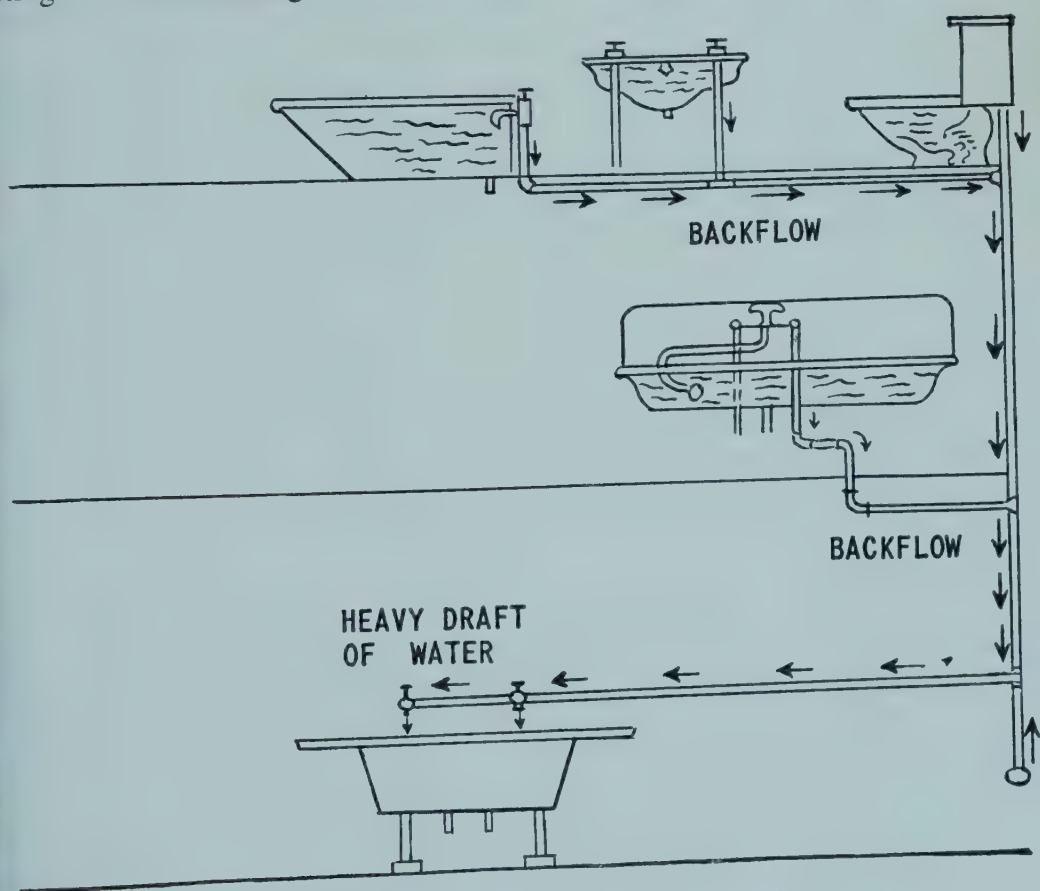


Fig. 41-6. Common backflow hazards in dwellings.

every washbowl, laundry tray, and water-closet, unless the water outlets supply-  
 them are either suitably protected against backflow or otherwise placed at such  
 height above the water surface in these fixtures that an adequate air gap is main-  
 tained, even when the fixtures are flooded, out of order, or operated improperly.



Common backflow hazards of dwellings are shown in Figure 41-6; other fixtures to be watched are sterilizers, water-cooled refrigerators, pumps, and boilers of all descriptions; also swimming pools. Although the water-supply system is normally under higher pressure than the drainage system, reductions in pressure occur at times of high rates of draft within buildings or from street mains. Water demands during fires as well as breaks in pipes and other untoward occurrences may actually place the water distribution system under suction. The unusual combination of circumstances that creates such conditions must be recognized if the dangers inherent in them are to be avoided. For further discussion of this matter, see Chapter 36.

**Sewerage Systems.** The wastes collected by the plumbing systems of dwellings and other buildings are discharged into the street sewers. The sewers and drains of a city are used for various purposes, the two most important ones being the removal of solid and liquid wastes from household and industry and the carrying away of rain water that falls on roofs, yards, sidewalks and streets. When the same system of sewers is used to carry both domestic sewage and storm water, it is called a *combined system*. When the storm water and sewage are carried in separate conduits, a *separate system* of storm and sanitary sewers is created.

**CHOICE OF SYSTEM.** The evolution of sanitary sewerage from surface and ground water drains makes the combined system the older and the one more commonly in use in older cities and crowded communities. It is generally cheaper than the separate system of sanitary sewers and storm drains, except where the storm water can flow off in street gutters without serious inconvenience from flooding or be conducted through short storm drains into nearby water courses or drainage channels. Where the sewage must be pumped or carried long distances or subjected to extensive treatment, the advantages lie with the separate system, as the quantity of sewage is less and its flow more constant. From a sanitary standpoint the separate system is usually mandatory. The choice of the two systems depends upon various engineering questions involving not only cost but also sanitary considerations concerned with the uses and volumes of the water into which excess storm flows from combined sewers must be discharged through storm-water overflows. For reasons stated below, health departments no longer permit the construction of combined systems without special investigation and serious study of the sanitary hazards involved.

**ARRANGEMENT OF SYSTEM.** Sewerage systems consists of *house sewers* or house drains that convey the sewage to the street sewers or *lateral sewers*. These unite in *main* or *district sewers*, and the latter sometimes combine into one or more *trunk sewers* of large size. *Relief sewers* are sometimes built parallel to the old sewers of inadequate capacity, and *underdrains* may be used in connection with the separate system to remove some of the ground water. *Intercepting sewers* parallel surface waters in order to intercept the sewage originally reaching them from combined sewers. The sewage is conveyed to a safer point of discharge. Interceptors are not designed to carry all of the flow during storms but are provided with overflows, so that the excess storm water is discharged into the water course at various points of overflow. They commonly carry but two or three times the dry weather flow. Depending upon the hydrology of the region, one or more per cent of the annual volume of sanitary sewage may still be swept through storm-water overflows into the waters that the sewerage system is intended to protect. The overflowing sewage is almost never

reated before discharge and constitutes a serious danger to the users of, the waters into which the mixed sewage and storm water are emptied.

The sewerage system of a community begins in the high-lying areas that are to be sewered and points progressively down-hill, increasing in size in much the same way as a river system. Where there are districts that drain naturally in a different direction from that taken by the main drainage system, or where there are areas that lie so low that their direct connection to the main system would require a general lowering of the trunk sewers, the sewers of these areas may terminate in pumping stations that lift the sewage through force mains into the main drainage system. Small pumping stations are generally made automatic in operation.

**QUANTITY OF SEWAGE.** The volume of sewage flowing in a separate system, or in a combined system during dry weather, does not differ materially from the water consumption of the community. In small American towns it may be as low as 40 or 50 gallons per capita daily. In large cities it may amount to 100 to 200 gallons per capita or more. Ground water enters the sewers in amounts varying from 10,000 to 100,000 gallons per day per mile of sewer, depending upon the tightness of the sewer joints and the wetness of the ground.

Intercepting sewers are commonly designed to provide for a flow of 200 to 300 gallons per capita daily. The amount of storm water is a function of the intensity and duration of flooding rainfalls and varies widely in different regions of the world. The flow of sewage fluctuates hourly, the maximum rate being from 50 to 100 per cent greater than the daily average. Still greater fluctuations occur in cities where large quantities of water are used for manufacturing purposes.

**SIZE AND GRADE OF SEWERS.** The factors governing the design of the sewerage system are the quantity of sewage to be handled and the velocity at which the sewage must flow to prevent deposition of solids and consequent clogging of sewers by accumulation of deposits that will decompose and release offensive odors. These factors determine the size and grade, or slope, of the sewers. The smallest sewer employed is generally eight inches in diameter, and the grades are so chosen that transporting velocities of flow in the vicinity of two feet per second for sanitary sewers and three feet per second for combined and storm sewers will be maintained. The higher value is needed to transport sand and gravel washed into combined and storm sewers from streets and areaways. Sanitary and combined sewers are laid to such a depth that they will drain the lowest fixtures in the buildings served (usually seven feet below the street line), except in tall buildings that have basements of such depth as to render this procedure uneconomical. The sewage from deep basements must be lifted by pumps or compressed-air ejectors into the street sewer. Storm drains can generally be kept at somewhat smaller depths.

Where the slope of the district is adequate, the grade of the sewer commonly conforms to the street grade; where the slope is inadequate, the sewers become progressively deeper, and it sometimes becomes economical to interpolate a pumping station that will lift the sewage back to the minimum depth below the street level. In flat country, sewage may be pumped repeatedly both at points intermediate in the system and at outfalls.

**SEWER APPURTENANCES.** To permit inspection and cleaning of the sewers, manholes are provided at all changes in grade and direction of the sewers; also at intermediate points in long straight runs of sewers that cannot be entered for



inspection and cleaning. Manholes are placed not less than 300 feet apart in small sewers; their distance may be increased to 400 feet or more for larger sewers.

Normally, sewers are not operated under pressure, as are water mains, but when obstructions are encountered, such as subways, stream beds, or deep valleys or ravines, the sewer may be placed under pressure locally and carried under the obstruction in pressure conduits known as inverted syphons or depressed pipes.

*Catch basins*, through which the street wash generally enters combined sewers, are trapped against the egress of sewer air. The water that stands in them sometimes serves as a breeding place for mosquitoes. Unless catch basins are frequently cleaned, the accumulating organic matter putrefies and the resulting odor may be worse than that of the sewer air. In separate storm sewers, untrapped *street inlets* leading directly to the sewers have long been used rather than trapped catch basins. Such inlets have also been used successfully on combined sewers.

Ordinarily, combined sewers are sufficiently flushed by periodic storms. Separate sewers, if laid on proper grades, need little or no flushing. Automatic flush tanks may be installed at the end of lateral sewers that are laid on flat grades, but these tanks are often troublesome, waste much water, and include a back-flow hazard. Hand flushing of sewers with fire hose is normally more satisfactory.

Since illuminating gas and gasoline vapors, as well as gases of decomposition arising from deposits of sewage matter, may accumulate in sewers, due precautions must be taken by workers entering manholes or large sewers for inspection, cleaning, or repair work. In the past there have been numerous fatalities from asphyxiation; there have also been sewer explosions. In order to avoid such occurrences, the sewers are generally ventilated by allowing a free flow of air from the sewers through the house drains and the house stacks.

**Hygienic Results of Sewerage.** As for the sanitary privy, it is difficult to adduce reliable statistical evidence of the hygienic benefits that accompany the introduction of sewerage into communities, because other sanitary improvements, notably in water supply, generally accompany the construction of sewerage works. A study by H. B. Cleveland for the State of New York for the period 1896 to 1915 established a median typhoid fever mortality of 12.6 per 100,000 for sewered communities and of 19.0 per 100,000 for unsewered communities. Leach and Maxcy (1926) list the following typhoid fever morbidity rates per 100,000 for 1924-1925 in communities of different sizes or types in Alabama:

Size or Type	Rural	500-1,000	1,000-2,500	2,500-5,000	5,000-10,000	10,000-25,000	25,000 and over
Morbidity	52	443	307	180	165	118	63

They interpret these figures as indicating relatively good protection in rural areas by virtue of lack of contact, and in larger cities by reason of community sanitation.

## SEWAGE DISPOSAL

The sewage collected by sewerage systems must eventually find its way into the natural drainage channels of the region, whether they be lakes, streams, or tidal waters. If these receiving bodies of water are to be protected against pollution, the sewage must be treated before being discharged into them. The needed degree of

treatment depends upon the receiving capacity of the body of water and the uses to which it is put. Both treatment and disposal involve a knowledge of the physical, chemical, and biological characteristics of sewage and the changes that accompany treatment and disposal.

**Composition of Sewage.** A city's sewage consists of the spent water supply mixed with the waste products of human life and activity and of the refuse from household and factory. This base flow is increased and modified by a certain amount of ground water which seeps into the sewers and, in the combined system, by varying quantities of rain water and street wash. Disintegrating and decomposing under the influence of mechanical abrasion and biological action, the sewage, as it flows, gradually becomes a more or less homogeneous suspension of fine particles in water, together with organic and mineral matter in solution. The longer the sewage flows or stands, the more its constituents become disintegrated; fecal matter and paper eventually become unrecognizable as such; bacteria and other saprophytes increase enormously and assist in breaking down the complex organic compounds by their scavenging activities. The respiration of the living organisms and incidental biochemical changes reduce the oxygen originally present in the water and it may finally disappear, so that from a fresh condition the sewage may become first stale and then "septic." Mixed with the decomposing organic matter and the swarming hosts of bacteria and other micro-organisms harmlessly engaged in their beneficent work of destroying the organic matter, there may also be organisms that have come from carriers of, or persons sick with, typhoid fever, dysentery, or other diseases.

Sewage is obnoxious to the senses because of its decomposing organic matter, but it is dangerous to health because of the possible presence of pathogenic organisms.

The most important constituents of sewage from the standpoint of treatment are the decomposable organic materials carried either in suspension or solution, such as fecal matter, urine, cellulose, fats, and soaps. The suspended mineral matter, though inert, is of importance because of its physical bulk. The concentration of impurities, or amount present in a given volume of sewage, depends upon the per capita volume of the sewage and the nature and magnitude of industrial activity. As a result it varies widely in different places.

The following diagram shows the normal concentration and physical state of the impurities in sewage of moderate strength.

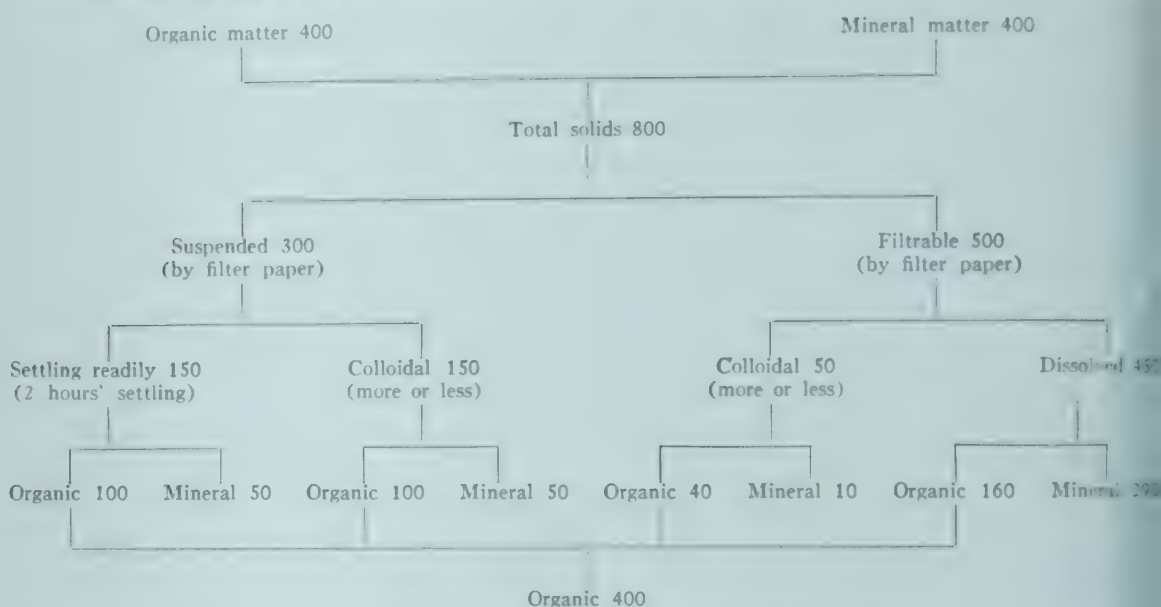
This diagram presents a general view of the nature and magnitude of the load of solids carried in sewage. It shows in particular how much of the sewage matter is capable of settling out and what is the general nature—mineral or organic—of the substances in suspension, in the colloidal state, and in solution. Disposal and treatment methods must take account of this physical state of the mineral and organic materials included in sewage if the problems involved are to be solved satisfactorily.

**SEWAGE ANALYSIS.** Most of the determinations commonly included in sewage analysis are the same or similar to those of water analysis (Chapter 37). The tests give indirect or inferential information about the properties of the sewage and must be interpreted as a whole rather than drawing information from the separate tests. The variety and interrelation of the tests commonly employed, according to



### CONCENTRATION AND PHYSICAL STATE OF SOLIDS IN SEWAGE OF MODERATE STRENGTH

Numbers are parts per million or milligrams per liter. They are generalized approximations, and considerable departures from them may be expected.



the general nature of the information they present, are shown in the following schedule.

#### Tests Measuring Organic Matter

Biochemical oxygen demand and relative stability

Volatile solids or loss on ignition (includes some mineral matter):

Suspended; settling and non-settling; dissolved

Organic nitrogen

Ether-soluble matter (fats)

#### Tests Measuring Mineral Matter

Fixed solids, or residue after ignition; suspended; settling and nonsettling; dissolved

Ammonia nitrogen (includes some organic matter)

Nitrite and nitrate nitrogen

Chlorides, hardness, alkalinity, and iron

#### Tests Measuring Both Organic and Mineral Matter

Total solids, or residue on evaporation: suspended, settling and nonsettling; dissolved

Hydrogen ion concentration

#### Tests Measuring Gases

Dissolved oxygen

Hydrogen sulphide

Carbon dioxide

#### Tests Measuring Living Organisms

Bacteria: total count, and coliform organisms

Other micro-organisms and larger organisms; animal and plant forms—notable indicators of sewage pollution.

The choice of tests depends upon the information desired. In general, sewage is analyzed for the purpose of predicting or determining its effect upon bodies of water.

water into which it may be discharged; for predicting the required degree of treatment; or for determining the efficiency of treatment processes.

The importance of the tests for solids and their physical state as well as their general organic or mineral nature has already been pointed out. The test for biochemical oxygen demand, which is not common to water analysis, is worthy of special consideration. This test measures the oxygen requirements of bacteria and other organisms (chiefly protozoa) as they bring about the decomposition of sewage matters. It is, therefore, perhaps the most significant measure of the putrescible load placed upon streams that receive the discharge from sewers or sewage treatment works, and in a similar way of the load placed upon biological sewage treatment processes. As this test is commonly performed, known quantities of the sewage are diluted with oxygen-saturated water and incubated in sealed bottles at 20° C for five days. The difference in the initial and final dissolved oxygen content presents the five-day, 20° C, biochemical oxygen demand of the sewage and permits its calculation in parts per million. Since the test is biologically activated, the oxygen demand exerted varies both with time and temperature. During the first stage of decomposition in which principally carbonaceous matter is oxidized, the "rate of demand" appears to be substantially constant. As the sewage matters that can be decomposed are gradually used up, however, while decomposition progresses, the "amount of demand" exerted gradually decreases. The first stage of decomposition extends over about 10 days at 20° C. After that, nitrification and other bacterial activities change the rate of demand, often increasing it. Warm temperatures stimulate the activity of bacteria and other water organisms and raise the rate of biochemical oxygen demand; cold temperatures lower it. The course of the first-stage

Table 41-1. Comparative average sewage analyses for American cities

Unless otherwise stated, results are expressed in parts per million

SEWAGE FLOW AND CONSTITUENTS	CHARACTER OF CITIES			
	Large Combined Sewers	Manufac- turing	Small Manufac- turing	Resi- dential
sewage flow—gallons per capita daily . . .	200	100	70	50
biochemical oxygen demand . . . . .	200	230	280	140
solids—Total . . . . .	1,350	1,160	730	600
Volatile . . . . .	450	640	450	390
Fixed . . . . .	900	420	280	210
Suspended . . . . .	210	390	240	340
Volatile . . . . .	140	290	200	260
Fixed . . . . .	70	100	40	80
Dissolved . . . . .	1,040	670	490	260
Volatile . . . . .	240	330	250	130
Fixed . . . . .	800	340	240	130
nitrogen—Organic . . . . .	8	24	24	18
Ammonia . . . . .	11	27	39	27
Sulfur . . . . .	25	37	...	...
bacteria—number per capita . . . . .	1,300 billion	...	...	...
uniform organisms—number per capita .	250 billion	...	...	...

After Metcalf, L., and Eddy, H. P., American Sewerage Practice, New York, McGraw-Hill Book Co.



biochemical oxygen demand and its variation with temperature can be formulated mathematically and offers an important means for predicting the behavior of receiving bodies of water into which sewage is discharged. Based upon the biochemical oxygen demand of sewage is the relative stability test in which the decolorizing of methylene blue added to the sewage indicates the exhaustion of oxygen through

Table 41-2. Amount and strength (p.p.m.) of industrial wastes

Waste	Production Unit	Gallons per Unit	Suspended Solids	B.O.D.	Remarks
Brewery	1 hbl. beer	470	650	1,200*	Spent grain dewatered
Cannery					
Asparagus	100 cases, #2 cans	7,000	30	100	Green
Beans	"	25,000	420	190	
Beets	"	3,700	1,530	2,600	
Corn	"	2,500	1,250	2,000	Whole kernels
Grapefruit	"	5,600	270	1,850	Grapefruit sections
Peas	"	6,500	—	1,700	Whole
Spinach	"	12,500	250	520	
Tomatoes	"	750	2,000	4,000	
Distillery	1,000 bu. grain mashed	600,000	360	230	Combined wastes
Packing House	100 hog units of kill	550	650	900	1 cattle unit equals 2½ hog, calf and sheep units
Milk Plant	1000 lb. raw milk and cream	340	540	570	General dairy
Paper Mill	1 ton paper	47,000	156	24	With bleaching
Paper Pulp Mill	1 ton dry pulp	85,000	1,720	110	Soda process
Tannery	100 lb. raw hides	800	2,400	1,200	Vegetable tanning
Textile Mill					
Kiering	1,000 lb. goods	1,700	—	1,240	Scouring and dyeing 100% grease wool
Bleaching	"	1,200	—	300	
Vat dyeing	"	19,000	—	140	
Wool scouring	"	240,000	—	125	

Data from House Document 266, 78th Congress, First Session

\* Ultimate biochemical oxygen demand.

the concomitant production of small amounts of hydrogen sulphide. The time elapsing before decolorization is a measure of the relative stability of the sewage. The longer the time, the more stable the sewage, or the less the biochemical oxygen demand.

Approximate values for the composition of the sewage from four groups of American cities are presented in Table 41-1, while Table 41-2 records pertinent information on the more important industrial wastes. Appreciable departures from the values given are to be expected.

The strength of industrial wastes is conveniently expressed also in terms of the number of people whose domestic sewage would exert the equivalent biochemical oxygen demand. This is known as the population equivalent of the waste. The basic per capita value for the five-day, 20° C, biochemical oxygen demand being ordinarily taken at 54 grams.

## DISPOSAL METHODS

As previously stated, a sewerage system constitutes a man-made arterial system of underground drainage channels that must be linked at the end of its course to the natural drainage channels of the region of which the sewered area is a part. Ordinarily, therefore, sewerage systems discharge with or without treatment into nearby water courses: rivers, lakes, or tidal waters. More rarely, they terminate in irrigation ditches that carry the treated or untreated sewage onto the land. The disposal of sewage into water is known as dilution; the disposal upon land as irrigation.

There are but few soils and climates that permit the use of sewage to irrigate crops under such conditions that all of the liquid is used up. In arid regions with open soils, large volumes of sewage can be absorbed; in wetter climates, the sewage discharged upon the ground passes through it and must be collected in underdrains that lead into nearby water courses. Irrigation then becomes a treatment rather than a disposal method, and the disposal of the drainage from the irrigation fields becomes a problem of dilution.

The discharge of sewage whether treated or not into streams, lakes, and harbors is by far the most common method of sewage disposal throughout the world. It can be applied satisfactorily whenever the water receiving the sewage is capable of being returned to a state of desirable purity by the operation of the forces of natural, or self-, purification that are inherent in all bodies of water (see page 1200).

**Pollution and Natural Purification of Receiving Waters.** The discharge of sewage into water sets into motion a series of physical, chemical, and biological reactions that are more or less interdependent. These must be studied if the mechanism of sewage disposal by dilution as well as the sanitary hazards involved are to be understood.

The problem of sewage disposal by dilution is largely a biological one and must be measured in terms of the changed conditions of existence to which the stream is subjected by pollution of the waters. If the pollutorial load is great, the first effect of the sewage upon the water is to make it turbid and impart to it a gray color. Sunlight is shut out, and green plants thus deprived of their energy for growth soon die. At first the organic matter of the sewage is fresh and is consumed by some varieties of fish which therefore gather near the outfall. Decomposition as a result of bacterial activity, however, soon begins and quickly renders the organic materials unfit for all except the most primitive organisms that subsist on decaying matter. These organisms, bacteria, fungi, and protozoa, develop in enormous numbers. As a result the stream soon becomes like an overcrowded, poorly ventilated space in which the demand for oxygen by the living organisms and the chemical changes produced by their activity soon exceeds the supply. Those forms of life which require a relatively high saturation of oxygen succumb. They include the fish and practically all other higher organisms. Since water that is saturated with oxygen contains but 1 per cent of this gas by volume against 21 per cent in the overlying atmosphere, the available oxygen supply is relatively more precious to the aquatic environment than is that of the atmosphere. When the current is not too rapid, much of the suspended matter carried into the stream by the sewage settles to the bottom and forms a pollutorial carpet, and in severe cases a deep deposit of sludge, on the



floor of the stream. Laid down in any appreciable thickness, these deposits decompose anaerobically except at their surface. The rate of decomposition is thereby slowed down, and the oxygen demand is decreased. Spring freshets generally remove the accumulated deposits and return the stream bed to relatively clean condition. New types of life make their appearance in the sludge, the most common organisms being small reddish worms which delve and burrow in the deposits and are factors in their stabilization. There develop, too, attached to the debris, masses of fungi and colonial protozoa that attract nutriment from the waters flowing past them.

As shown in Figure 41-7, these changes are confined to a short stretch of river below the outfall. There follows a much longer river stretch in which the processes

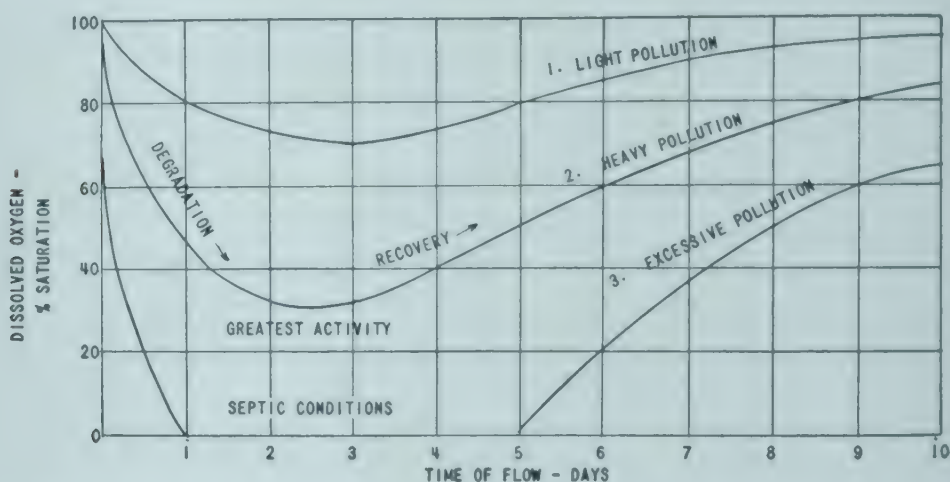


Fig. 41-7. Degradation and recovery of a polluted stream as measured by its content of dissolved oxygen.

of decomposition that have established themselves reach their greatest activity. From a physical standpoint this second zone is characterized in heavily polluted streams by a grayish color of the water; sticky blackened sludge deposits with offensive odor; evolution of gas bubbles especially during the warmer months; foul sewage and privy odors. Decomposition of the complex organic materials is marked by reducing and splitting processes. Soluble and gaseous compounds are formed. By successive stages the end-products become simpler in structure, until they can no longer support the micro-organisms whose activity is responsible for the processes of decomposition. So as long as the water contains dissolved oxygen no serious nuisance results. In grossly polluted streams, however, the dissolved oxygen is sometimes completely exhausted. The organisms of decay then satisfy their need for oxygen by abstracting it first from mineral substances, such as nitrites, nitrates and sulphates, and finally from the organic matter itself. Decomposition then takes place under anaerobic or septic conditions and the river may become extremely offensive. The greater the reduction of dissolved oxygen, however, the greater fortunately becomes the rate at which oxygen is absorbed at the water surface. This is called re-aeration. Eventually decomposition slackens as the available organic materials are consumed, and a point is finally reached when re-aeration balances the demand for dissolved oxygen and finally overbalances it. A new store of dissolved oxygen is then gradually accumulated. More highly organized life re-establishes

shes itself, and the bacteria and protozoa that have held sway are reduced in numbers. The length of river stretch occupied by this zone of active decomposition will vary with the seriousness of pollution, with the time of travel and with the temperature. It is not necessary that the stream should become truly septic. When pollution is relatively light, the zone of active decomposition is not of great length. In heavy polluted rivers, however, it may extend over many miles.

There attaches to this second zone a stretch of water in which the stream gradually recovers its former appearance and life. The outward appearance of this zone is marked by gradually clearing water, by bottom deposits that are granular rather than sticky and have no offensive odor, and by absence of gas bubbles. Judged by chemical standards this third zone is one of mineralization in which the last vestiges of decomposable organic matter are stabilized. Dissolved oxygen gradually increases to complete saturation. Nitrogen end-products are carried to nitrites and finally to nitrates, sulphur to sulphates, and carbon to carbonates, thus completing the cycle of these elements in nature. Green algae make their appearance and are followed by larger aquatic vegetation. By photosynthesis they assist in reoxygenating the water. Small animal forms of life, crustacea, rotifers and insect larvae, some of them important food for fish, reappear.

Below the three zones of visible pollution and natural purification is found the cleaner water zone in which the forces of self-purification continue their beneficent work. This zone is characterized largely by the normal flora and fauna of rivers. The enrichment of the food supply resulting from pollution and self-purification may indeed cause a marked development of all forms of cleaner water life. Green plants, large and small, predominate, and natural and desirable conditions are once more established.

In streams, the zones discussed neither occupy a fixed position in the channel, nor are they sharply bounded. In the same stream the zones may overlap due to variations in temperature and river flow. These cause a shifting of the zones. Sometimes they are extended, sometimes contracted. The cycle of self-purification may be retarded, interrupted, or accelerated by the entrance of new waste materials, by clean or polluted tributary waters, by dams, rapids, ponds, or reservoirs. Toxic waste products, acid mine wastes, strong alkalis, and oil may profoundly modify the course of natural purification by destroying life so essential to self-purification or by interfering with re-aeration. Since the amount of oxygen that can be dissolved in water decreases as the water temperature rises (14.7 p.p.m. at  $0^{\circ}\text{C}$  against 7 p.p.m. at  $29^{\circ}\text{C}$ ) while the rate of biochemical activity or oxygen demand increases with rising temperatures, doubling for every rise of  $10^{\circ}\text{C}$ , it follows that there are profound seasonal changes in the self-purification of streams, offensive conditions being more marked in summer than in winter, except when ice cover prevents re-aeration. This phenomenon of oxygen adsorption from the atmosphere is similar to the renewal of oxygen in the blood stream by the lungs during respiration. The larger the surface of contact between water and air and the more frequent the change of surface the more rapid is the rate of reoxygenation. This explains why swift streams can absorb oxygen more rapidly than quiescent bodies of water. It must be remembered, however, that biological activity resulting in decomposition and its associated deoxygenation as well as re-aeration requires time for completion. It should be apparent, therefore, that a lake or artificial reservoir may store the



polluted waters for days, weeks, or months and thereby become a factor of great importance in the natural or self-purification of a water course. The old adage that running water purifies itself is an incomplete and hence misleading statement of facts. Quiet water purifies itself also, the changes being slower with respect to re-aeration but usually more rapid with respect to sedimentation of suspended matter, reduction of bacteria, and the like. The degree of natural purification accomplished, furthermore, it is not a question of distance but of time of travel.

Similar, but opposite in character to deoxygenation and re-aeration, is the production of carbon dioxide and its removal to the atmosphere at the water surface. The analogy between the respiration of a stream and of the higher vertebrates is, therefore, quite complete. Sea water dissolves about 20 per cent less oxygen than fresh water.

The biological changes taking place in a sewage-polluted stream are illustrated by the figures in the following table for the Illinois River below the point of entrance of the sewage of Chicago.

Table 41-3. Bacteria and plankton below point of heavy pollution, Illinois River, October, 1921, to August, 1922

TIME OF FLOW, HOURS	DISTANCE OF FLOW, MILES	POLLUTIONAL PLANKTON, % OF TOTAL	BACTERIA ON GELATIN, NUMBER PER ML.
0	0	60	1,106,500
12	23	65	681,000
36	59	58	219,050
135	107	36	38,230
178	120	20	15,015
222	164	20	25,192
291	261	16	13,486

After Purdy, W. C., U. S. Pub. Health Bull. 198, 1930.

**REQUIRED DILUTION OF SEWAGE.** The minimum amount of water required to dilute sewage in streams and other bodies of water must usually be sufficient to provide, directly or indirectly, enough oxygen to satisfy the biochemical oxygen demand of the sewage matters. Although the re-aeration as well as the deoxygenation of polluted waters can be formulated in mathematical terms, the presentation of certain overall values will better meet the purposes of this book. Thus it has been established by experience that in normal water courses from 2.5 to 4 cubic feet per second of diluting water must be provided to receive into a stream, without the creation of offensive conditions, the raw, or untreated sewage of one thousand people. The Chicago Drainage Canal was designed on the basis of 3.3 cubic feet per second for one thousand people. Rapidly flowing streams need to supply less than this value; sluggish streams and standing bodies of water have to provide considerably more water. The presence of trade wastes in the sewage may materially increase the dilution required. Oily wastes float on the surface and form scums that may interfere with the absorption of oxygen from the air. Wastes rich in organic matter, such as packing house or tannery wastes, consume much oxygen, i.e., their population equivalent is very high. Tidal waters and large lakes, as well as streams, may act as diluting agencies.

No general dilution requirements governing the discharge of treated sewage

to water courses have as yet been formulated in the United States. Some years ago the British Royal Commission on Sewage Disposal adopted the figures shown in Table 41-4 for English practice:

Table 41-4. Dilution requirements governing discharge of treated sewage for English practice

Condition of Sewage	Required Dilution (Volumes of Water to One Volume of Sewage)	Suspended Solids Less than (Parts per Million)
crude .....	More than 500	—
settled .....	300-500	150
chemically precipitated .....	150-300	60

For lower dilutions the treatment plant effluent is required to contain less than 10 parts per million of suspended matter and have a biochemical oxygen demand of less than 20 parts per million in five days at 65° F. In studying these requirements, it must be remembered that English sewage is two to four times as strong as American sewage.

Of recent years the principle of regulating dilution on the basis of maintaining an adequate oxygen balance in the water acting as a sewage carrier has been widely recognized in situations in which nuisance is to be prevented. Where streams and other bodies of water serve as water supplies, however, consideration must be given primarily to the permissible bacterial loading of water purification plants. This is generally a more rigid requirement, and the volume of sewage discharged, as well as the degree of treatment to which the sewage should be subjected, must be adjusted accordingly.

The International Joint Commission on the Pollution of Boundary Waters between Canada and the United States based the permissible pollution of boundary waters upon their use for water supply purposes and adopted a standard of less than 500 coliform organisms per 100 ml. as a yearly average. This corresponds to a required dilution of 2 cubic feet per second per capita, a figure about 500 times as large as that needed to prevent a nuisance. The permissible loading of water purification plants is discussed more fully in Chapter 39.

**Outfall and Other Dilution Works.** The location and construction of sewer outfalls has an important bearing upon the success of sewage disposal by dilution. In order to be effective it is necessary to have the sewage thoroughly and quickly dispersed through the water. This occurs automatically in moving streams. In standing bodies of water, special means must be provided to effect dispersion. In lakes, the location of sewer outfalls relative to that of the intakes of waterworks and that of bathing beaches must be carefully considered, and the travel of bacteria with currents induced by wind and temperature must be studied. In coastal waters the effects of the tides must be taken into account in connection with the protection of bathing beaches and shellfish layings.

Sewage is generally warmer and lighter than the water into which it is discharged. If sewage is emptied into a receiving water near its surface, therefore, it will ride on top of the diluting water, will not mix readily, and will tend to form a "sleek" which can be noticed for many miles. This sleek will become quite



offensive during hot weather. In coastal waters, sea gulls feed upon the waste materials and may possibly fly from the sewage fields to the water reservoirs of nearby towns.

In order to disperse sewage in quiescent receiving waters, it should be introduced at or near the bottom of the water. The sewage then tends to rise and become well distributed as it makes its way to the surface. Dispersion is further aided by providing a number of outlets at sufficient distance from each other to avoid interference. Large outfalls have been placed at depths of 40 or 50 feet, and a large number of distributing nozzles situated on pipes branching over several acres of harbor bottom have been employed to ensure adequate dispersion.

The natural purification inherent in streams and other bodies of water may be controlled successfully also by engineering works that either supply water for dilution, during periods of low flow, from impounding reservoirs or from natural bodies of water in nearby, but different, drainage areas, or that increase the length of time required for polluted river waters to pass down stream. Examples of these practices are: (1) the Chicago Drainage Canal created by reversing the flow of the Chicago River and carrying its waters together with adequate quantities of clean water abstracted from Lake Michigan through a canal into the Illinois and Mississippi Rivers; (2) numerous impounding reservoirs in this and other countries that release stored water during periods of low flow; and (3) the impounding reservoirs of the Ruhr Valley in Germany that increase the time of flow of the Ruhr River in a 47-mile stretch from 18 to 84 days as well as exposing large new areas of water surface to re-aeration and sunlight. Another example of controlled dilution is found in the fish ponds of some European cities, in which settled sewage is mixed with clean river water to create conditions of existence favorable to the cultivation of fish and raising of ducks. Fish ponds of this kind are analogous to fertilized fields. Large crops of organisms that serve as food for fish and for ducks develop in the aquatic meadows of the ponds.

**Hygienic Aspects of Stream Pollution.** Considering the hygienic aspects of stream pollution with special reference to the pollution of water supplies, it is important to remember that pathogenic organisms do not multiply in the ordinary water of our streams but diminish in number, or die away, at a more or less constant rate.

It follows that recent pollution is the most dangerous, and that waters stored in reservoirs and lakes becomes more and more safe for use as length of storage increases. The longevity of pathogenic organisms is much greater in cold water than in warm water. This is one reason why water-borne epidemics of disease are more common in winter and early spring than in summer, and in northern climates than in southern climates.

The viability of the typhoid bacillus is similar to that of *E. coli*. Hence the death rate of this index organism of sewage pollution can serve as a yardstick of what happens to typhoid bacteria. Some of the results of studies by the U. S. Public Health Service on the Upper Mississippi River during the summer and winter months are shown in Table 41-5. The reduction in bacteria growing on agar at 20° C in 48 hours and at 37° C in 24 hours is shown as well as the reduction in *E. coli*. This permits a comparison of their relative significance.

Laboratory studies of the die-away of *Salmonella typhosa* in clean water record

Table 41-5. Average bacteria remaining in Upper Mississippi River below point of maximum concentration

	20° C Count on Agar		37° C Count on Agar		<i>E. coli</i>	
	Summer	Winter	Summer	Winter	Summer	Winter
Initial number in thousands per ml.	605	72	558	37	3.4	0.5
Percent of maximum remaining after flow of 26.8 hours	14.0	80.6	10.4	44.5	4.9	12.2
1260.0 hours	3.2	1.6	3.1	0.4	0.1	0.1

U. S. Public Health Bulletin 203, 1932.

death rate at 0° C of 55 per cent per day and of 80 per cent at 10° C, the time survival being halved for every rise in temperature of 10° C. The viability in water of the cysts of *Entamoeba histolytica* is relatively much greater. It is almost 10 days at 0° C. The length of survival, however, is cut in three by every rise in temperature of 10° C.

**Legal and Economic Aspects of Stream Pollution.** Whereas it is true that hygienic and sanitary considerations materially affect the use of rivers and waterways as vehicles for the reception, transmission, and ultimate disposal of sewage, the question is primarily an economic one. The power of streams to remove suspended matter and the ability of natural bodies of water to oxidize and destroy offensive substances represent a natural resource that should be utilized just as far as this can be done with safety and without offense. For each river there is a limit to the amount of permissible pollution. The reasons for this limit are not always the same but vary according to the use that is made of the water of the river. No universal standard can, therefore, be wisely set up or maintained. When the extent of pollution is such as to affect public health in any way by any reasonable use of the river, the sanitary aspect of the situation should control.

Long experience has demonstrated clearly and unmistakably that it is possible to purify polluted water and make it reliably wholesome. Some waters, however, are so grossly polluted that the load upon the purification works would be too great to produce an hygienically safe water by economical treatment methods. When this is so, it is usually better to seek a less polluted supply or to require treatment of the sewage or industrial wastes that are polluting the supply. This is a problem in operative sanitation that will be touched upon later.

**Nuisances Caused by Industrial Wastes.** Not infrequently the greatest nuisance in streams and other bodies of water is due not so much to domestic sewage as to industrial wastes that are discharged directly, or allowed to flow into the receiving water through the sewers. For example, the discharge of spent dye liquors may color the water of a stream for many miles; wastes from gas works may form a descent films upon the surface of the water and add phenolic taste-producing compounds; wastes from paper mills may release noxious amounts of hydrogen sulfide; and acid iron wastes from galvanizing works may cause a rusty discoloration of the water that paints the rocks and submerged stumps along the shores for many miles. When nuisances of this character arise, it is wise and proper to install suitable waste-treatment plants. Industrial wastes may complicate the purification of water



even more than sewage itself. Industrial wastes may also interfere with the proper operation of sewage treatment works. Copper and other toxic wastes, for example, may render biological treatment of sewage and sludge inapplicable, and carbohydrate wastes may interfere with the normal operation of the activated-sludge process. As previously shown, the population equivalent of some industrial wastes in terms of their biochemical oxygen demand may be quite high. In some communities it may even exceed the load imposed by domestic sewage.

Some industrial wastes are toxic to man as well as to the lower animals.

### TREATMENT METHODS

By appropriate processes, sewage and industrial wastes can be treated so that the decomposable organic matter is removed or oxidized and the bacteria and other organisms removed or killed. Complete purification is not attempted, as it would be too expensive; purification is incomplete, the degree of purification secured being adjusted to the needs of the situation. In general, sewage treatment works are built to remove as much of the suspended matter and decomposable organic matter as is necessary to enable the effluent to be discharged into some waterway without causing offensive conditions. In some places greater emphasis is placed on the removal of polluting substances with the object of protecting shellfish beds and bathing beaches, or reducing the "load" on water filters.

**Fundamental Principles of Sewage Treatment.** If the waste materials from human habitations and industries retained their identity during their travel through the sewerage system and could be removed from the transporting water as readily as they are added, a sewage treatment plant would be a relatively simple unloading station at which the wastes would be separated from the carrying medium for disposal in concentrated form. Unfortunately, the physical condition in which many of the waste products occur in sewage makes simple unloading impossible, and the obnoxious nature of the matter that finds its way into sewage renders it undesirable. Toward the end of the last century it was recognized that sewage treatment must rely upon physical separation of some of the objectionable waste matters and upon biological modification of the remainder in much the same way as this is accomplished in Nature's household by the self-purification of a polluted stream. Someone, indeed, has compared a sewage treatment plant to a river wound up at one spot to localize the area in which purification is accomplished. Activity is controlled and intensified, and many of the reactions proceeding slowly and fortuitously in the waters of polluted streams are accomplished more quickly in sewage treatment works by creating conditions that will induce, develop, or stimulate the forces of natural purification.

The fundamental processes of sewage treatment are: (1) separation of the suspended matter from the liquid sewage; (2) destruction of the putrescible organic matter in the liquid sewage looking to final mineralization by the processes of biological action; (3) transformation of the sewage sludge to a condition of stability and inertness by biological action; and (4) destruction of the bacteria and other micro-organisms in the liquid effluent or their removal from it.

The processes involved may be classified as follows: (1) **primary processes** such as screening, skimming, sedimentation, and chemical precipitation; (2) **sec**

ary processes, such as subsurface irrigation, broad irrigation, intermittent filtration, contact and trickling filter treatment, and activated sludge treatment; (3) finishing processes, such as disinfection and disposal of the effluent in water or on land; and (4) sludge treatment and disposal, such as digestion, air drying, mechanical dewatering, incineration, and disposal of the sludge on land or in water.

The processes are by no means clear-cut. They overlap at many points; they are used singly or in many different combinations.

**Primary Treatment.** The object of primary treatment is the removal of those suspended solids that are readily separated from the sewage by physical means alone, namely, screening or settling. The unloaded material is often subjected to further treatment in order to secure its safe and economic disposal.

**SCREENING.** There are two types of sewage screens: coarse screens and fine screens, including comminuting screens.

*Coarse Screens.* These consist of gratings of iron bars seldom less than an inch apart which hold back only the largest floating objects found in sewage, such as sticks, paper, and rags. They are used chiefly in connection with sewage pumping stations in order to prevent injury to the pumps, but they are also employed in treatment works and on outfalls to accomplish in a rough way what is done with a greater degree of effectiveness by fine screens.

Two types of coarse screens are widely used: racks placed in an inclined position in the channel of sewage flow, and cages lowered in duplicate vertically into the sewage, one being removed while the other is being cleaned. Racks may be cleaned by hand or by mechanical means.

*Fine Screens.* Fine screens are made of wire mesh or perforated metal plates with openings seldom more than  $\frac{3}{8}$  inch and often less than  $\frac{1}{16}$  inch in their smallest dimensions. They retain many of the finer sewage particles, including some solid matter. Fine screens clog rapidly and require special mechanisms to keep them clean. A great many different types of screens have been devised. They generally operate through the sewage in the form of disks, drums, or endless chains that usually are cleaned by brushes, sometimes by air or water jets, or by the water pressure created by the motion of the screen.

The amount of material screened from sewage varies from 1 to 30 cubic feet per million gallons of sewage, according to the size of rack and screen openings and the composition of the sewage. Fine screens remove from 2 to 20 per cent of the suspended matter and from 5 to 20 per cent of the biochemical oxygen demand. These are relatively low efficiencies. The use of fine screens, therefore, is generally restricted to special circumstances, such as the protection of water courses against unsightly sewage matters. In this case screening may be supplemented by chlorination. Screenings may be pressed to remove much of the entrained water. They may then be disposed of by being burned under a boiler or in an incinerator provided for that purpose, buried in land, or turned over to the local garbage and refuse department for disposal. Since they are so small a portion of the removable matter, at the same time, so unsightly and obnoxious to handle, it has become common practice to comminute the screenings and return them to the sewage. The screenings are generally comminuted in place by rotating the screen against a cutting device. This combination is called a comminuter. If screenings are disposed of on land, they should be covered sufficiently to prevent odors and fly-breeding.



When screens are operated in connection with grit chambers, the screenings are usually covered with grit to fill low-lying areas near the treatment works.

**SEDIMENTATION.** It was pointed out in connection with the design of sewerage systems that the velocities of flow in the sewers had to be maintained sufficiently high to prevent deposition of part of the burden of solid matter carried by the sewage. This tendency of sewage solids to settle out under the influence of gravity is the most generally useful process of sewage treatment. Some of the larger and heavier solids, such as sand, gravel, and other gritty mineral matter, settle out promptly when the velocity of flow is reduced below that commonly maintained in the sewers; other solids, constituting the bulk of the settling solids and including much of the suspended organic matter, require low velocities and long periods of time to settle through the depth of settling tanks; still others, fine suspended matter and matter in the colloidal state, will not settle even during protracted quiescence, but they can be removed in substantial amount by the addition of coagulating chemicals. Substances lighter than water, oil, grease, and floating matters, will rise to the surface when the velocity of flow is reduced and can then be skimmed off.

This behavior of sewage solids during relative quiescence is made use of for the following purposes: removal of grit or detritus; removal of oil and grease; and removal of settling solids. Related to these processes are the disposal of the materials removed and sometimes the further treatment of these materials prior to disposal.

*Removal of Grit or Detritus.* Most of the heavy mineral or gritty solids suspended in sewage have their origin in street wash and occur, therefore, chiefly in combined sewerage systems. Their removal becomes important when the grit subjects pumps and screens to excessive wear, makes the removal of sludge from settling tanks difficult, or interferes with other treatment processes. Grit may be separated from the flowing sewage by reducing the velocity of flow to about a foot a second for a minute or two. The structures in which this is accomplished are called grit chambers. They generally take the form of elongated channels of somewhat greater cross-sectional area than the outfall sewer to bring the velocity to the required value and to provide for the requisite detention period and grit storage. Since storm-flows are extremely variable, flexibility of control is usually obtained by constructing a number of parallel channels that can be thrown into operation as needed. The grit is removed from time to time by hand, by mechanical sludge elevators, or by hydraulic means. It is then used for fill or is buried. If the velocities of flow are well controlled, the grit will be relatively clean mineral matter; if not, it may contain sufficient organic matter to render the resulting sludge offensive. More or less continuous grit removal by mechanical scrapers and the washing out of the organic matter as the grit is brought to the surface of the chamber permit the use of a single grit chamber and yield a relatively clean grit.

Periods of detention of 15 minutes or more have been employed to separate from sewage the most readily removable suspended matter irrespective of its character. The resulting sludge is called detritus and is often offensive. The amount of grit collected varies with the character of the district drained and the frequency and intensity of storms as well as with the conditions of flow in the chambers. At velocities of one foot per second and detention periods of one or one and one-half

minutes, from 1 to 12 cubic feet of grit may be expected per million gallons of sewage treated.

*Removal of Oil and Grease.* Oil and grease find their way into sewage from household and industry, more particularly from garages. When discharged into waters receiving untreated sewage, these substances, together with other light or floating solids, form unsightly scum or "sleek" on the water surface. In sewage treatment plants, they produce similar conditions on settling tanks and may interfere with some of the treatment processes. For these reasons it may be desirable to provide skimming tanks which will permit the floating matter to rise to the surface of the sewage whence it may be removed intermittently or continuously by hand or by mechanical devices. Detention periods in excess of one minute, but less than 15 minutes, are generally provided and the flow may be horizontal or vertical. To prevent deposition of solids and to aid the separation of the oil and grease from the sewage, air may be blown into the tank from below. Skimmings are generally small in bulk but are often drawn from the tanks together with much water. Some water can be removed by placing the material in a separating tank whence the water is drawn off or by running it onto drying beds similar to sludge-drying beds to be discussed later. The drained material is generally added to sludge-digestion tanks. Sometimes it is burned or buried. The amounts collected vary greatly depending upon the enforcement of regulations governing the discharge of waste oil into the sewers.

*Removal of Settling Solids.* The proportion of solid material removed in grit chambers and skimming tanks is relatively small. The bulk of the settling solids, including most of the organic settling solids, is carried through such treatment devices and requires prolonged sedimentation with or without chemical treatment. Sedimentation tanks are commonly used in advance of the biological processes of sewage treatment to decrease the load on these or to remove substances that will interfere with their proper operation. They are also employed after biological treatment to retain the settleable solids produced in, or unloaded from, these processes. Finally, they are often used without other treatment methods to lessen the amounts of suspended solids discharged into bodies of water. Used in this way, sedimentation is of great importance, not only because it reduces the load placed on a receiving water, but also because it prevents the formation of sludge deposits that accumulate to localize and often intensify the biochemical oxygen demand of sewage matters.

The efficiency of sedimentation processes varies chiefly with the time permitted for settling to take place, the strength of the sewage, and the character of chemical treatment, if any. The greatest proportion of sedimentation takes place at the beginning; little added clarification is obtained beyond the second hour. When chemicals are used to improve settling, the detention period that will produce the most advantageous clarification is influenced by the time it takes for the necessary chemical reactions and floc-formation to be completed before sedimentation becomes fully effective. Stirring and flocculating devices and tanks are, therefore, often introduced to prepare the sewage for sedimentation. The stronger the sewage, the greater the rate of removal of suspended matter by sedimentation; but it will take longer to reduce the suspended matter to the same absolute effluent value in a strong sewage than in a weak one. Unaided by chemicals, sedimentation will remove in



from one to four hours between 40 and 70 per cent of the suspended matter and between 25 and 40 per cent of the five-day biochemical oxygen demand from sewage of medium strength. Average values are 60 per cent for suspended matter and 35 per cent for biochemical oxygen demand. Chemical precipitation, if well conducted, may reduce the suspended matter by 70 to 90 per cent and the biochemical oxygen demand by 50 to 85 per cent. To attain such high efficiencies, however, large quantities of chemicals may have to be applied, and the cost will be relatively high.

We may classify the various tanks employed for the removal of settling solids as follows: plain sedimentation tanks arranged as single or two-story units, septic tanks, and chemical precipitation tanks.

**PLAIN SEDIMENTATION TANKS.** Settling tanks are called plain when the force of gravity alone produces the clarifying of the sewage. In order to permit this force to operate to greatest advantage, the velocity of flow must be checked. Longitudinal displacement velocities less than 10 inches per minute are employed, and the detention time varies from 30 minutes to many hours. Periods greater than two hours are unusual and seldom economical. In modern works, fill-and-draw operation of the tanks has given way to continuous flow. The path of the sewage is generally horizontal in primary units, i.e., tanks preceding biological treatment or operating in plants having no further treatment except perhaps disinfection (Figure 41-8, A). Tanks in which the flocculent sludge produced by biological treatment is settled are often arranged to pass the sewage in downward, upward, and radial flow. In such units the flocculent solids settling from the sewage travel in opposite direction to the liquid and assist in sweeping out the lighter flocculent materials by aggregation. Vertical displacement is generally held below one inch per minute (Fig. 41-8, B).

It is essential for satisfactory operation of plain sedimentation units that the sludge be removed before it becomes septic and gas ebullition lifts the settled solids back into the flowing sewage. For this reason mechanical sludge-removal devices have come into use. These can be operated intermittently or continuously, as required. In principle they consist of scrapers that move the sludge to an outlet sump, whence the sludge is drawn off under the influence of hydrostatic pressure or by pumping (Figs. 41-8, C and D).

Continuous removal of the solids settling from the flowing sewage is accomplished without the aid of mechanical devices in two-story tanks in which the upper compartment serves as a settling chamber and the lower compartment as a storage chamber in which the settled solids may be carried to partial or complete digestion. The best known tank of this type is the Imhoff or Emscher tank (Fig. 41-8, E). The processes obtaining in the settling compartment are those of plain sedimentation; the ones acting in the sludge compartment are those of anaerobic sludge decomposition, called digestion. This treatment of sludge will be discussed later. It can also be accomplished in separate digestion tanks into which the sludge is pumped from the sedimentation units (see Fig. 41-8, F). The gases and scum rising in the digestion chamber of Imhoff tanks are not permitted to enter the sewage but pass into gas vents or collecting chambers that may occupy up to 20 per cent of the tank surface. The gases include methane of high fuel value. Hence

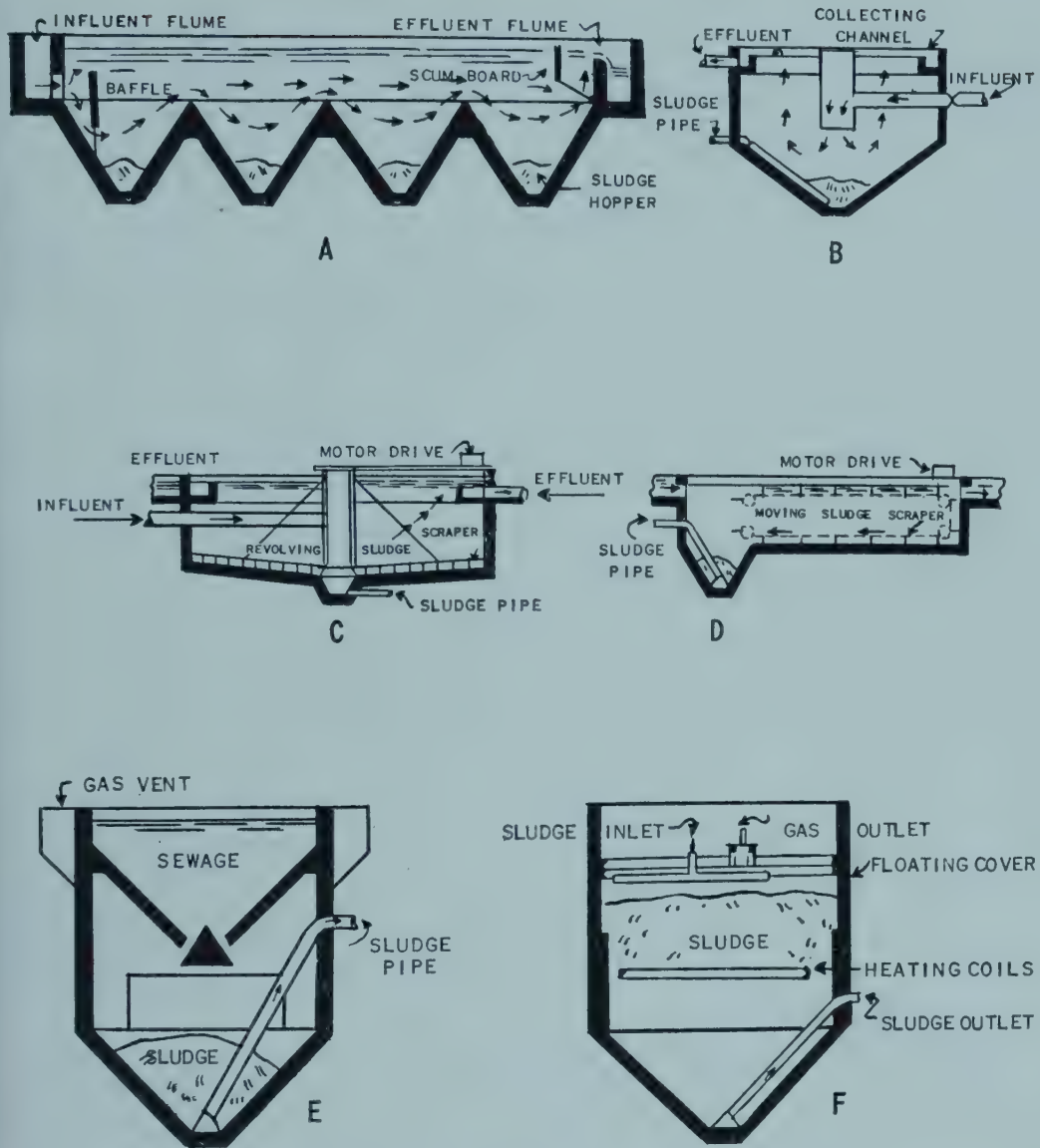


Fig. 41-8. Types of sedimentation and sludge digestion tanks.

*A*, rectangular settling tank with hopper bottom; *B*, circular or Dortmund settling tank with vertical flow; *C*, round settling tank with revolving scraper; *D*, rectangular settling tank with longitudinal scraper; *E*, rectangular two-story or Imhoff tank (transverse section); *F*, circular separate sludge digestion tank with floating cover.

The gases from both two-story and separate digestion tanks are generally captured and utilized in the treatment plants of larger communities. The sludge storage capacity of Imhoff tanks varies with the magnitude and duration of winter temperatures. For technically complete digestion, two cubic feet of sludge storage per capita are commonly provided in the northern United States.

Settling tank loadings are generally expressed in terms of the volume of sewage treated per unit of tank area per unit of time. A value of 900 gallons daily per square foot of tank surface is common for ordinary sewage solids. This figure is sometimes increased for secondary settling tanks for activated sludge and trickling filter humus.



**SEPTIC TANKS.** Septic tanks hold the sewage from 8 to 24 hours or longer and retain the sludge for such long periods of time that it becomes septic. Liquefaction and gasification of the organic matter take place and the sludge is reduced in volume. Gas-lifted solids may form a heavy scum on the tank surface. The effluent from single-story septic tanks frequently contains much gas-lifted suspended matter and may have a high biochemical oxygen demand; the sludge removed is usually incompletely digested and hence offensive; and the use of other sedimentation and digestion devices is generally more economical. Except for smaller installations, usually for isolated dwellings, septic tanks have, therefore, generally been displaced by Imhoff tanks or by plain-sedimentation units in combination with separate sludge digestion tanks.

**CHEMICAL PRECIPITATION.** Sedimentation may be hastened and increased by the use of chemicals. Lime (calcium oxide), copperas (ferrous sulfate), chlorinated copperas (containing ferric chloride), aluminum sulfate, ferric sulfate, and ferric chloride singly or in combination may be used to coagulate the suspended matter by forming flocculent masses of iron or aluminum hydroxides. The process is similar to the removal of color and turbidity from drinking water by coagulation. When the sewage itself contains the necessary amount of iron—often derived from the waste liquors of iron pickling processes—lime only may be needed. Several hundred pounds of chemicals are required per million gallons of sewage treated and from 50 to 85 per cent of the biochemical oxygen demand of the sewage is removed by this treatment process.

Clarification of the coagulated sewage by rapid filtration of the settled sewage through quartz sand or crushed magnetite which is cleaned periodically by backwashing has not established itself because of many operating difficulties. The acidifying of sewage with sulfuric acid or sulfurous acid fumes obtained by burning sulfur or roasting pyrite has been employed successfully for recovering grease from the sewage of wool-scouring plants and towns.

The relative incompleteness of purification and cost of chemical precipitation in comparison with biological treatment methods has generally confined its application to special conditions, such as the needs of resort communities in which seasonal requirements and populations vary widely. The small amount of equipment needed to convert plain sedimentation tanks into chemical precipitation units is then in favor of the process.

**Biological Treatment.** The effluent from sedimentation tanks still contains relatively large quantities of putrescible organic matter in suspension and solution. The removal of this putrescible matter by converting it to a settleable state or by transforming it into relatively stable compounds, is the object of biological sewage treatment. The methods developed can be arranged in the following historical order: irrigation, intermittent sand filtration, contact beds, trickling filters, and activated sludge. Each of these processes represents an attempt to simplify procedures and decrease the size of the treatment plant required to accomplish the desired results.

The results of biological treatment are closely associated with the development upon a supporting medium, such as a filter of soil, sand, or broken stone, or such as flocculent sewage solids, of gelatinous growths of bacteria (*zooglea*) and other organisms, including fungi, protozoa, and higher forms of life. Sewage in contact

with the active surfaces of the supporting medium is exposed to numerous physical, chemical, and biological forces, including adsorption, the life activities of microorganisms, the action of enzymes, chemical coagulation, and the tendency of dissolved and colloidal substances to move to or away from an interface. Maintenance of areobic conditions is essential to the success of all normal biological sewage-treatment processes, and the result attained is sometimes referred to as oxidation, or "moist combustion." It is well to remember that the principal result of the most advanced treatment methods is the conversion of dissolved and finely divided solids into settleable solids. These form a secondary sludge which is called "humus" when it is derived from trickling filters and "excess" or "waste" sludge when it comes from activated-sludge tanks. Both of these secondary sludges are highly putrescible.

For comparative purposes we may summarize the normal loading and efficiency of common biological processes as shown in Table 41-6.

Table 41-6. Normal loading and efficiencies of biological sewage treatment plants

Process	LOADING		PER CENT REMOVAL OF	
	Thousands of Gallons per Acre Daily	Persons per Acre	Suspended Matter	Biochemical Oxygen Demand
Surface irrigation	0.75-20	10-2,000	...	...
Subsurface irrigation of settled sewage	5-10	100-200	...	...
Intermittent sand filtration				
Raw sewage	20-80	250-1,000	85-95	90-95
Settled sewage	50-125	500-1,500		
Biologically treated sewage	up to 500	up to 500		
Trickling filter treatment of settled sewage in 6- to 10-foot beds *				
Low-rate operation	1,000-4,000	12,500-50,000	70-92	80-95
High-rate operation	20,000-25,000	250,000-300,000	65-92	65-95
Activated sludge treatment of settled sewage in 15-foot tanks * †	10,000-20,000	125,000-250,000	85-95	75-95

\* Including final sedimentation of effluent.

† Removal reduced in high-rate treatment.

**IRRIGATION.** There are two types of irrigation projects: surface irrigation, also known as sewage farming, and subsurface irrigation.

In surface irrigation, raw, settled, or more completely treated sewage is applied intermittently to land, where it serves as food for crops. The principal value of the applied sewage, however, is the water itself. The sewage is distributed by ditches and other channels as in ordinary irrigation. It is applied to the land of crops by flowing over sloping fields from an upper to a lower ditch (ridge, surface, or broad irrigation), by passing through numerous furrows between beds (bed, or ridge and furrow irrigation, or land filtration), or by flooding underdrained fields surrounded by banks (flood irrigation). The sewage may also be sprayed upon the land from a system of movable pipes. A great variety of crops is raised on sewage farms. Among them are: grasses, beets, and other fodder, garden truck, corn, and



wheat; and walnuts and oranges. Considerations of hygiene demand that direct pasturage of dairy animals and the raising of produce that is to be consumed raw, even though sewage does not come into direct contact with it, as in bed irrigation, should not be permitted on sewage farms. The crops harvested from sewage farms frequently pay the expenses of operation, but they seldom return the interest on the investment. Only in arid regions is irrigation profitable. Surface irrigation is not successful with clayey soils. The degree of purification obtained by irrigation is usually satisfactory, both chemically and bacteriologically.

For small installations a satisfactory method of disposing of sewage by irrigation after sedimentation is to discharge it through three-inch or four-inch open-jointed tile pipes that are laid in the ground 18 to 36 inches deep in rows 5 to 10 feet apart. In tight soils the tile drains may have to be surrounded with gravel and sand. Subsurface irrigation is particularly applicable to suburban and rural conditions (see Fig. 41-4).

**INTERMITTENT SAND FILTRATION.** With this method the sewage is flowed intermittently onto beds of sand, especially prepared for the purpose. The quantities are such that the sewage quickly seeps into the sand and draws air behind it into the bed. A resting period of many hours then affords an opportunity for aeration and oxidation or stabilization of the organic matter. The filtration area is usually divided into beds that are surrounded by earth embankments which cover the distributing pipes. The beds are generally underdrained with tiles laid about 10 feet apart in fine material, or as much as 100 feet apart in coarse material, their depth below the surface varying from two to eight feet. After a few weeks or months the beds become clogged and must be raked to loosen the surface, the accumulated deposit on the sand being scraped off. In winter the beds may be plowed into ridges that will support a sheet of ice above furrows through which the sewage will flow. The bed is thereby kept from freezing and cracking (see Fig. 41-9).

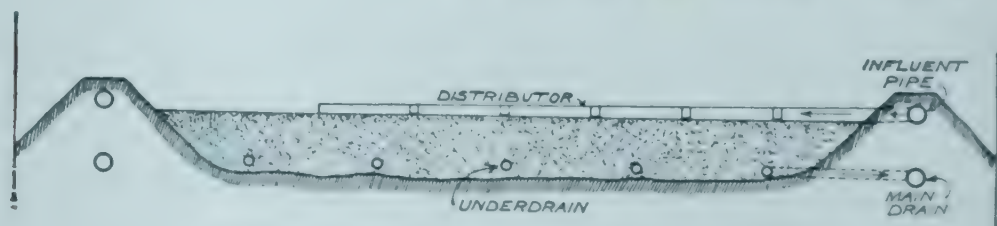


Fig. 41-9. Cross section of intermittent sand filter.

The efficiency of intermittent sand filtration is higher than that of any other process; the effluent is quite clear and nonputrescible. Economy limits the method, however, to regions where suitable, convenient, and adequate areas of sandy soil exist. Intermittent filtration may be employed to advantage also following other biological processes of treatment where an effluent of especially high quality is to be secured to protect water supplies. After biological treatment the rates of filtration may be stepped up to values that are limited only by the permeability of the sand.

**TRICKLING FILTERS.** Trickling filters, also called "sprinkling filters" and "percolating filters," consist of beds of coarse material such as broken stone, coke, or clinkers over which the sewage is sprinkled and through which it percolates to

nderdrains laid on a tight floor beneath. The entire bed is arranged to ensure adequate ventilation in order that the oxygen requirements of the biological slimes that cover the contact material may be met at all times. The sewage solids transferred to the slime are not permanently retained in the bed but are unloaded more or less intermittently in the effluent, from which they must be removed by secondary sedimentation. As shown in Table 41-6, trickling filters are operated at low or high rates. At low rates of operation solids are stored in the filter for considerable periods of time; at high rates "unloading" is more or less continuous. The seasonal unloading of low-rate filters produces solids that have served as abulum for vast numbers of living things and are often quite well stabilized and humus-like. The sludge from high-rate filters is relatively more putrescible.

The sewage is sprayed onto the beds as continuously as possible through fixed nozzles or by rotating or traveling sprinklers that are operated by the discharging sewage or by power (see Fig. 41-10, A). The beds vary in depth from 3 to 10

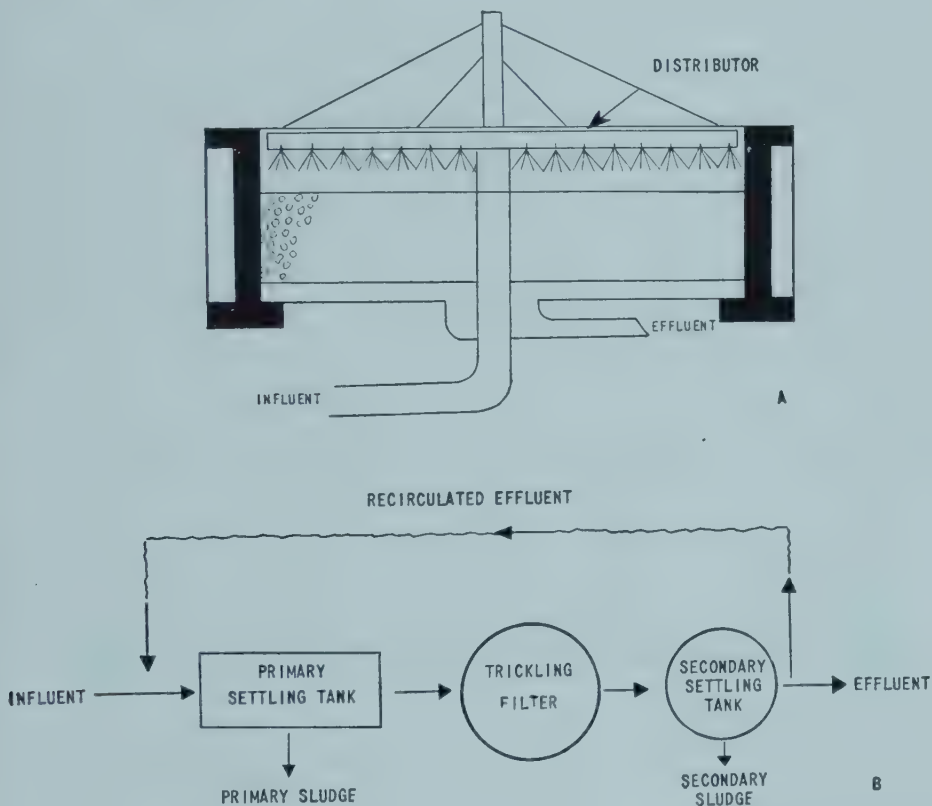


Fig. 41-10. Trickling filter.

A, transverse section of circular filter with rotary distributor of sewage; B, schematic illustration of recirculation of effluent through filter.

et, coarser material sometimes being used for the deeper beds, and shallow beds often being arranged serially in pairs. Formerly, trickling filters were operated intermittently because it was believed that a resting period was needed as for sand filters. To ensure proper hydraulic performance of the nozzles, the filters may have to be preceded by specially designed dosing chambers.

The efficiency of trickling filters varies with the strength of the sewage and the rate of operation. The efficiency of high-rate filters can be increased by recirculat-



ing the effluent through the bed. Recirculation is employed also to keep up the flow through the bed during periods of low sewage discharge to the treatment plant (see Fig. 41-10, B). In a sense, recirculation exposes the entire depth of filter to approximately the same concentration of sewage. The filters of small plants may be covered to prevent odor and fly nuisance and to keep the filters warm during cold weather. The occurrence and control of trickling filter flies are discussed later.

**ACTIVATED SLUDGE.** If air is blown into sewage standing in a tank, the particles of colloidal and suspended matter will flocculate and form an anchorage and source of food for zoogeleal biological growths much like the slimes covering the contact medium of sewage filters. The resultant flocs are known as "activated sludge"; once formed, they will persist and grow in bulk so long as they are brought into contact with new sewage and the oxygen requirements of the activating organisms are satisfied. In principle, the process resembles that of filtration, the sand grains or stones of sewage filters being replaced by sludge particles suspended in the liquid.

Aerobic conditions and mixture can be obtained in two ways. Finely divided air can be forced through the tank by the use of perforated pipes, diffusers, and other devices, or the sewage can be agitated mechanically, new surfaces of liquid being brought into contact with the atmosphere from which they absorb the required amount of oxygen. The first is termed *bubble aeration*, the second *mechanical aeration*. In both methods the sludge is kept in suspension throughout the liquid. Combinations of diffused air and mechanical agitation can also be employed. Ordinarily the volume of activated sludge is about 20 per cent of the

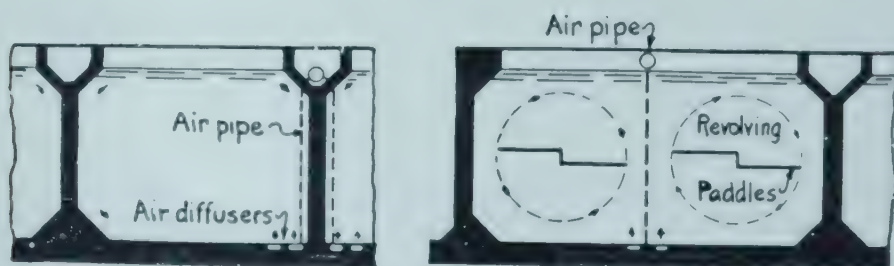


Fig. 41-11. Activated sludge aeration units.

A, transverse section of rectangular battery of diffused air units producing spiral flow.  
B, transverse section of rectangular unit employing mechanical agitation by paddles, aeration being aided by diffused air.

volume of the incoming sewage and the time of aeration varies from four to six hours. An aeration tank is shown in Figure 41-11. In activation by aeration, the amount of air used varies from 0.5 to 1.5 cubic feet per gallon of sewage. In all types of tanks a velocity of 1.5 feet per second is sufficient to keep the sludge in suspension and will permit surface aeration provided that the tanks are so designed that the sewage is well mixed during travel. The activated sludge is permitted to pass out of the tanks together with the treated sewage and is then separated from it by sedimentation. Vertical or mechanically cleansed secondary settling tanks are used quite commonly (see Figs. 41-8, B, C and D).

The sludge collected from the sewage is in part returned to the influent to the aeration units (about 94 per cent), and in part wasted as excess sludge (6 per cent). Modifications of the conventional process include: *reaeration* of the sludge after minimal aeration of the sewage; *step aeration* by adding sewage at two or more points along the aeration channel; *two-stage aeration* by dividing treatment between two similar units and by return and wasting of the sludge within each stage or the return of second-stage excess sludge to the first stage; and *high-rate treatment* by short-period aeration and either very high or very low sludge return.

**Disinfection of Sewage.** None of the processes so far described can be relied upon to furnish an effluent free from pathogenic organisms, despite the relatively high degree of purification obtained by the best processes. In order to protect oyster beds, waterworks, or bathing beaches, therefore, sewage is sometimes disinfected.

Disinfection is obtained by means similar to those used in water purification. Gaseous chlorine and chloride of lime are most commonly used. The quantities of chlorine required per million gallons of fresh sewage are approximately 50 to 100 pounds for raw sewage, 40 to 80 pounds for settled sewage, 25 to 50 pounds for chemically precipitated sewage, and 20 to 40 pounds for biologically treated sewage. For stale or septic sewage these values may have to be doubled. To secure satisfactory disinfection a chlorine "residual" must be maintained during an adequate contact period. A residual of 0.5 parts per million after 15 minutes of contact is often specified, but the required time of contact may be up to two hours.

In addition to a reduction of 95 to 99 per cent of the bacteria, the biochemical oxygen demand of chlorinated sewage is reduced, the decrease varying with the condition of the sewage treated. This is of importance in connection with the disposal of sewage and in keeping sewage fresh in extensive collection systems or long outfalls. Chlorine will also control odors about sewage treatment works.

**Bacterial Efficiency of Sewage Treatment Processes.** By way of recapitulation, the following average figures show the relative bacterial efficiency of the common processes of sewage treatment:

PROCESS	PERCENTAGE REMOVAL OF BACTERIA
Coarse screens . . . . .	0 to 5
Fine screens . . . . .	10 to 20
Grit chambers . . . . .	10 to 25
Sedimentation . . . . .	25 to 75
Chemical precipitation . . . . .	40 to 80
High-rate trickling filters . . . . .	80 to 90
Low-rate trickling filters . . . . .	90 to 95
Activated sludge process (less in high-rate operation) . . . . .	90 to 98
Intermittent sand filters . . . . .	95 to 98
Chlorination of raw or settled sewage . . . . .	90 to 95
Chlorination of biologically treated sewage . . . . .	98 to 99

**Choice of Sewage Treatment Methods.** The choice of treatment methods depends upon numerous considerations, including the nature of the sewage to be treated, the allowable character of the effluent with reference to the use made of the water into which it is to be discharged, the availability of suitable areas of land at proper elevation, and the costs of construction and operation.



The most common combinations of sewage treatment methods employed in the United States are:

*Primary treatment*—coarse screens (combined systems); grit chambers (combined systems); skimming tanks (sometimes); plain settling tanks with separate sludge digestion; pre-aeration tanks in advance of biological treatment (sometimes).

*Biological treatment*—trickling filters, or activated sludge tanks, both followed by secondary settling tanks.

## SEWAGE SLUDGE

The solids removed by the different treatment processes constitute the principal by-product of sewage treatment. Excepting screenings and the deposits obtained in grit chambers, the solids removed are called sludge. If the daily volume of sewage treated runs into millions of gallons, the amount of sludge to be disposed of will run into thousands of gallons daily. Because of its bulk, putrescibility, and potential inclusion of organisms of disease, the sanitary disposal or utilization of sewage sludge presents one of the most troublesome problems associated with the management of sewage works. The sludge obtained by different sewage treatment methods varies greatly in amount, chemical composition, and physical characteristics. Table 41-7 presents a general statement of these variations.

The relatively large volumes of sludge produced by the activated sludge process are due not only to the removal from liquid sewage, as by the trickling filter, of colloidal as well as finely divided suspended matters, but also to the watery consistency of the sludge produced. In this connection it should be realized that decreasing the water content of a sludge from 98 per cent (2 per cent solids) to 96 per cent (4 per cent solids), i.e., doubling the content of solid matter, decreases the volume of the sludge by about 50 per cent. The high weight of chemically precipitated sludge is accounted for by the inclusion of the precipitated chemicals and constitutes an inherent disadvantage of this treatment process. Drying renders undigested sludges relatively stable by depriving the saprophytic organisms of the moisture necessary to the free function of their life processes. Digestion or anaerobic decomposition not only reduces the bulk of the sludge by producing a less watery sludge, but results also in a loss of solid material by liquefaction and gasification.

**Sludge Treatment.** Treatment of the sludge produced by different sewage treatment processes is undertaken with a view to rendering the final disposal of the sludge economical and inoffensive. Utilization of the sludge solids as fertilizer and of combustible gases produced by the sludge during digestion is generally of secondary importance. The treatment processes commonly employed are: digestion, air drying; vacuum filtration; and heat drying with or without incineration. These processes may be used singly or in combination.

**DIGESTION.** Saprophytic bacteria and other organisms find in sewage solids an abundant source of food, different groups of organisms utilizing different types of food substances originally contained in the sludge or produced in the course of decomposition. As the nutritive elements are used up, the sludge becomes more stable and, in its final state, inoffensive to sight and smell. It is then said to be well digested. The end-products of digestion are gases, liquids, and a residue of mineral and relatively undecomposable organic matter. Losses by gasification and liquefaction of solid materials, as well as increased density and compaction of the

Table 41-7. Normal \* amount and character of sludge produced by different processes of sewage treatment

TREATMENT PROCESS	GALLONS OF SLUDGE PER MILLION OF SEWAGE	POUNDS OF DRY SOLIDS PER MILLION GALLONS OF SEWAGE	PER CENT SOLIDS IN SLUDGE	PER CENT ORGANIC MATTER IN DRY SOLIDS	APPEARANCE	ODOR WHEN FRESH	PUTRESCIBILITY AND DIGESTIBILITY	RESPONSE TO AIR DRYING
Plain sedimentation								
Fresh primary sludge	2,000	1,200	5	72	Gray, slimy	Offensive	Rapid at favorable temperatures	Poor; satisfactory only in thin layers
Digested primary sludge **	700	750	13	38	Black, tarry	Inoffensive, tarry	Nonputrescent	Excellent even in thick layers
Chemical precipitation †								
Fresh primary sludge	4,000	1,800	5	67	Black, slimy	Sometimes objectionable	Rapid at favorable temperatures	Poor
Digested primary sludge	1,500	1,200	10	38	Brown	Inoffensive	Nonputrescent	Good
Plain sedimentation and trickling filtration								
Secondary sludge ††	400-1,000	300-450	8-5	68	Brown, flocculent	Inoffensive	Slowly putrescent, readily digested	Poor; satisfactory only in thin layers
Digested primary and secondary sludge	1,100-1,300	950-1,100	10	37	Black, tarry	Inoffensive, tarry	Nonputrescent	Excellent
Plain sedimentation and activated sludge treatment								
Secondary sludge ††	3,500-12,000	550-700	2.5-0.7	68	Brown, flocculent	Inoffensive, earthy	Rapidly putrescent readily digested at favorable temperatures	Poor; satisfactory only in thin layers
Digested primary and secondary sludge	1,400-2,000	1,200	10-7	33	Black	Inoffensive, tarry	Nonputrescent	Good

\* Appreciable departures from these values are to be expected.

\*\* Also Imhoff-tank sludge.

† Varying with types and degree of treatment.

†† Varying with rate of filter operation.



solid particles, reduce the bulk of the sludge to a marked extent. Sludge digestion is an anaerobic process as oxygen cannot diffuse sufficiently rapidly into sludge from water or atmosphere to satisfy the demand of the living organisms. The gases of decomposition, therefore, are substances such as methane, carbon dioxide, hydrogen, hydrogen sulphide and nitrogen; chiefly methane (65 to 80 per cent by volume) and carbon dioxide. The normal daily volume of gas produced on a per capita basis is about 1.0 cubic foot from plain sedimentation sludge and 1.1 to 1.5 cubic feet when trickling filter humus or excess activated sludge is digested together with the solids resulting from primary sedimentation or when sedimentation is increased by chemical precipitation. Industrial wastes, rich in organic matter, may increase the gas yield appreciably. The high methane content of sludge gas makes its fuel value (670 British thermal units per cubic foot) equal to or greater than that of most illuminating gases and renders it possible to utilize the gases of decomposition for various treatment plant purposes, such as the heating of buildings and digestion tanks and the production of power for pumping, air compressing, or other mechanical work.

Sludge digestion proceeds best when the raw solids are seeded with well-digested material and when the temperature of digestion is kept uniform and high. Seeding inoculates the raw solids with the proper bacterial flora and, by the strong buffering action of well-digested sludge, serves also to keep the hydrogen ion concentration of the digesting sludge close to the favorable neutral point. Artificial reduction of acidity by lime may have to be resorted to in the absence of seeding. Digestion is hastened by heating digestion units to favorable temperatures. Sludge held at 90° F. for example, will digest in about half the time that is required at 60° F. Heat is provided by the sludge gas. This is either burnt under a hot-water or steam boiler, in a heat exchanger within the tank itself, or in a gas engine the cooling water and exhaust gases of which serve as the heating medium. Optimum temperatures are 95° F (mesophilic) and 130° F (thermophilic). Values just below the lower optimum are commonly employed in practice.

The sludge digestion compartment of Imhoff tanks cannot be heated successfully, because most of the heat is lost to the sewage flowing through the settling compartment. Where digestion is to be speeded up by heating, therefore, separate digestion tanks are employed. These tanks are covered to capture the sludge gases and are usually heated by hot-water coils (see Fig. 41 8, F). The sludge storage capacity of digestion tanks for plain-sedimentation solids is generally about 1 cubic foot when the normal digestion temperature is 60° F, and the required capacity should be doubled or halved for a fall or rise of 30° F, respectively. When trickling-filter humus or excess activated sludge are to be digested with plain-sedimentation sludge, they are generally returned to the influent of the primary settling tanks and permitted to settle with the primary solids before being digested. Digester capacity must then be increased by 30 to 60 per cent for trickling filter humus and by 70 to 130 per cent for excess activated sludge. Thickening the sludge before digestion reduces the digester volume. The overflow liquor from separate digestion tanks is usually foul and is returned for treatment to the sewage entering the plant, in general without ill effects.

Utilization of the gases of decomposition requires a thorough appreciation of the explosion hazards involved.

**AIR DRYING.** The most common method of dewatering sludge is its air drying by flowing it in layers 1 to 12 inches thick onto underdrained sand, gravel, or under beds. Part of the moisture retained in the sludge is evaporated, and part percolates through the bed into the underdrains. The time required for drying varies with climatic conditions and the character of the sludge. Well-digested sludge is less offensive and dries more readily than relatively fresh sludge. In northern climates the drying area required varies from one to three square feet per capita for well-digested sludges; in southern climates the area required can be reduced. The lower figure is for primary sludge, the higher for mixtures of primary and activated sludge. Trickling filters add 0.6 square foot of drying area to the lower figure, and chemical precipitation adds 1.0 square foot. Glass-covered drying beds may require but half the area of open beds. When the sludge has dried sufficiently to become spadable it is removed from the beds.

**VACUUM FILTRATION.** Attempts to dewater sludge in filter presses and centrifuges in which the excess liquid is either pressed or thrown out of the sludge have given way to continuous vacuum filtration in which the sludge is dewatered by suction and forms a sludge cake. The waste liquor is highly offensive. The sludge is generally coagulated with chemicals in advance of filtration, ferric chloride being commonly employed as the conditioning agent. The amount of ferric chloride needed to coagulate digested sludge, which is highly alkaline, can be greatly reduced by washing the alkalinity out of the sludge with clarified sewage. This is called *striation*.

**HEAT DRYING.** The sludge cake produced by air or mechanical drying is sometimes further dewatered to commercial dryness (not more than 10 per cent moisture) by driving off excess water by heat. This is an expensive process. To offset its cost, the dry sludge may be ground and sold as fertilizer. Instead of recovering the sludge as fertilizer, the drying temperature may be raised to the point of ignition of the sludge which is then incinerated and provides the heat necessary to maintain the drying process. Direct recovery of heat by incineration of the sewage solids makes sludge digestion less advantageous. Fresh sludge in the dry state has a calorific value equal to that of lignite or peat, while digested sludge has but half its value. The fuel value lost from the sludge by digestion is more or less recovered as combustible gas.

**Sludge Disposal.** Among the ways for the final disposal of sewage sludge are: pumping into water, lagooning and trenching, filling and fertilizing.

**DUMPING.** Some of the larger seacoast towns discharge the wet or dewatered, fresh or digested sludge into the sea, either by direct pumping or by loading it into sludge vessels or barges in which it is carried out to sea and dumped in deep water. This method of sludge disposal is also used by some of the cities situated on great lakes or large rivers.

**LAGOONING AND TRENCHING.** Where there is much low-lying land in the vicinity of the disposal plant, it is a relatively simple matter to throw up dikes or utilize natural depressions in the ground to receive the wet sludge, which then forms a sludge lagoon. In these the sludge dries slowly. Where much land is available, the sludge is left in place until the lagoon is filled; where land is scarce, the sludge is moved after drying and disposed of in other ways. The odors rising from sludge lagoons that receive undigested or partially digested solids may be troublesome.



Sometimes the sludge is run into trenches which are covered with earth. After the sludge dries it is worked into the soil by plowing. The disposal area required then naturally large.

**FILLING.** Dried sludge is well suited to fill low-lying land, and much waste land can be reclaimed in the neighborhood of treatment works by careful filling.

**USE AS A FERTILIZER.** The use of sewage sludge as a fertilizer continues to be advocated as a measure of conservation. All sewage sludges contain nitrogen and some phosphorus and potash. Digested sludges, furthermore, are humus-like and possess soil-building properties. Municipalities are sometimes able to dispose of wet sludge or sludge cake to farmers who use it for fertilizing purposes. A charge is often made for the material. Dried activated sludge has excellent fertilizing qualities and is especially useful on lawns and golf greens. The revenue derived from the sale of dry sludge may, under favorable conditions, offset the expense of dewatering.

**Hygienic Aspects of Sludge Utilization.** A number of sanitary hazards are involved in the use of sewage sludge for the fertilizing of crops. These are not confined to the transmission of bacterial diseases, such as typhoid fever and dysentery through contaminated vegetables or other agricultural products that are consumed raw, but include the possible spread of virus diseases such as infectious hepatitis and of amebic dysentery and worm infections, notably ascariasis. Under favoring conditions, furthermore, sewage sludge may pollute the soil and contribute to the transmission of hookworm infection.

In a general way, fresh solids are more dangerous than well-digested sludge and wet solids more so than partly dry solids. Air-dried solids are relatively safe and heat-dried solids distinctly safe. Although the survival of pathogenic bacteria in digesting and air-dried sludge may be short, Cram (1943) has reported that the cysts of *E. histolytica* survive in sludge for 10 days at 30° C; the eggs of *Ascaris* for six months (10 per cent survival); and the eggs of hookworm for 4 days at 30° C. She has also found *Ascaris* and hookworm ova to be very resistant to air drying. The heating of pulverized sludge to 103° C for three minutes, on the other hand, destroyed all *Ascaris* eggs.

**Choice of Sludge Disposal Methods.** The choice of sludge disposal method like that of sewage disposal depends upon numerous factors, such as the general location of the community, the demand for sludge as a fertilizer, the economics of sludge treatment, and the availability of land for disposal.

**Management of Sewage-Treatment Works.** Proper management of sewage treatment works is as important as proper design, and is more difficult to secure. Neglect not only makes the effluent unsatisfactory but leaves the works themselves in an offensive condition. Neglect of small plants is more common than of plants large enough to require full-time employment of one or more trained attendants.

Another frequent cause of failure is that treatment works are allowed to become outgrown, so that the plant becomes overloaded. The sewers of a city are usually designed for a long period in advance—40 or 50 years—but this is not the custom with treatment works, for the reason that such works can ordinarily be enlarged when necessary. If they are enlarged at the required time, this is sound policy because methods of treatment are constantly improving and it is desirable to take advantage of these improvements.

The treatment of sewage is a highly technical matter, and it is desirable to have the works in charge of qualified personnel with a laboratory at their disposal. Tests of the sewage before and after treatment should be made regularly in order to ascertain the efficiency of the process. Tests should also be made of the water into which the sewage is discharged. Where plants are of large size, such tests are made daily; but where plants are too small for the employment of a full-time chemist, tests should be made regularly by some controlling authority. Herein lies one of the functions of health departments.

**Treatment Plants as Nuisances.** If sewage treatment works are properly designed and carefully operated, and if they are enlarged from time to time to meet the needs of the growing community and changing demands upon the receiving bodies of water, they will not cause offensive conditions. Opprobrium is, nevertheless, generally attached to the areas in which such works lie and results in a recognized deterioration of property values. If the sewage reaching the treatment works is stale, odors may arise and reach distances up to perhaps half a mile from the plant, depending upon the amount and character of sewage treatment, the local topography, prevailing direction of the wind, humidity in the atmosphere, and other conditions. Modern treatment works, however, can be designed and operated to keep complaints within reason.

High winds will carry the spray from trickling filters or activated sludge tanks for several hundred feet with inevitable pollution of the air. Little hygienic significance seems to attach to this phenomenon, however. At certain seasons of the year swarms of minute flies (*Psychoda*) breed in trickling filters. These flies are troublesome in the immediate vicinity of such works because they enter the mouth, nose, ears, and eyes of plant personnel. Too small to be kept out of habitations by ordinary window screens, their radius of flight fortunately is small. Filter flies can be kept in check by DDT residual spray on walls of the bed and adjacent buildings and other shelters.

## COOPERATIVE SANITATION

What appears to be needed for the most effective utilization of water resources is some method of cooperation by which needed sanitary controls can be exerted at least expense. It is unbusinesslike to compel the treatment of the sewage of a large upstream city in order to protect the water supply of a small city lower down, when pure water can be furnished the latter in some better and cheaper way. Legislation that clothes water authorities with power to prevent the pollution of streams with sewage, but does not give them power to compel the purification of water or to control pollution by industrial wastes, is unfortunate. It naturally leads to litigation rather than cooperation, and it may retard rather than hasten necessary sanitary reform. State authorities are ordinarily entrusted with this matter and may in with the authorities of neighboring states to create interstate authorities that can deal with natural hydrographic areas that overlap state boundaries. Interstate waters and the boundary waters of the country are also the concern of the national government. In whatever form the authority is constituted, the idea of cooperation should prevail. There should be, in particular, a rational distribution of the burden of water purification and sewage treatment, and an equitable adjustment of cost



between the parties interested, thus decreasing the total expense of sanitary measures required and utilizing natural resources to greatest advantage.

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## REFUSE DISPOSAL

GORDON M. FAIR, M.S., DR.ING.

The refuse disposal problem is one of economy, convenience, and general cleanliness rather than hygiene. Odors rising from fermenting garbage or the processes connected with garbage disposal do not injure the public health directly, yet they are offensive to the sense of smell and interfere with the enjoyment of an otherwise healthy environment. From this standpoint their elimination is an important matter. Garbage attracts numerous insects, particularly flies which feed in unprotected garbage receptacles and sometimes rise in swarms from dumps in which garbage, manure, or other organic wastes are permitted to accumulate. These places also provide food for rats and other vermin, and may support large rodent and insect populations. As shown later, the feeding of garbage to hogs increases the incidence of trichinosis both in the swine and human population. Accumulating rubbish creates a fire hazard as well as being offensive to the olfactory senses and affording an opportunity for mosquito breeding in tin cans and other discarded receptacles that become filled with rain water and that shelter the insect larvae and pupae until maturity. Ashes and street dust are easily lifted by wind and when blown about may irritate eyes, nose, and throat. The indirect effects of refuse disposal on the public health are, therefore, many, and the sanitary disposal of wastes, more particularly garbage, is of concern to health departments, although needed operations are left to other municipal departments.

**Composition and Quantities of Refuse.** The general term "refuse" is applied to all of the solid waste material from human habitations not carried by the sewers. Such it includes ashes, rubbish, garbage, street sweepings, and dead animals, as shown in the classification following. Excreta, which form part of the solid wastes of a community, although included in this classification, are considered in Chapter 41.

- A. Public Refuse—municipal responsibility for collection and disposal.
  1. Originating in homes, hotels, institutions, markets, stores.
    - a. Garbage: Wastes from the handling, storage, sale, preparation, and consumption of food.
    - b. Rubbish:
      - (1) Combustible: Packaging materials, yard trimmings, discarded home furnishings.
      - (2) Noncombustible: Metallic and ceramic waste materials, and dirt.
    - c. Ashes: Residue from fires.
  2. Originating in public ways and vacant lots.
    - a. Street refuse: Sweepings, leaves, dirt.
    - b. Dead animals.



**B. Industrial Refuse**—private responsibility for disposal.  
Solid wastes from industrial operations.

The quantity of waste material that must be removed from cities is very large. The total amount of refuse is, roughly, half a ton per capita per year, and it varies with the size of the community, its industrial and mercantile activity, and its geographical situation. The amount of garbage varies from less than 100 to upward of 500 pounds per capita per year; the weight of rubbish from less than 200 to more than 500 pounds per capita per year; and the amount of ashes from less than 400 to more than 600 pounds per capita per year. In addition, from 20 to 80 dead animals must be disposed of annually per 1,000 population. Both the quantity and character of the refuse vary with the seasons, the maximum amount of ashes being produced in the winter and the maximum amount of garbage in the summer, keeping the total weight of refuse about the same in all months of the year.

Ashes weigh from 1,150 to 1,400 pounds per cubic yard; garbage, from 800 to 1,500 pounds; street sweepings, from 700 to 1,800 pounds; and rubbish, from 200 to 700 pounds.

**Collection of Refuse.** There are two general methods of refuse collection: the mixed system and the separate system. The choice of the system depends to a large degree upon economic considerations and the type of ultimate disposal. With the *mixed system*, all of the wastes are placed in a single receptacle by the householder. They are then collected in single conveyances and transported to the point of disposal where they are disposed of jointly. With the *separate system*, garbage, ashes, rubbish and other wastes are placed in separate containers by the householder and collected in separate wagons or trucks to be separately disposed of, usually in different ways.

The proper choice of receptacle for the storage of the various types of refuse will keep down nuisances in the neighborhood of human habitations. Garbage should be placed in covered metallic containers that render the contents inaccessible to dogs and other animals and do not permit the breeding of flies. Cities in which garbage is incinerated may require that all garbage be wrapped in paper before being deposited in the container. This keeps the can clean, prevents rapid fermentation in summer and freezing in winter, causes the householder to drain the garbage before wrapping it and placing it in the can, avoids the transportation of unnecessary amounts of water, and permits collection of the garbage in uncovered vehicles. Garbage cans should be thoroughly scoured from time to time. Ashes are commonly placed in covered metal containers. Rubbish is usually stored in barrels or tied into bundles. Because of its high market value as a fertilizer, stable manure, no longer an important element of municipal refuse, is usually removed by private individuals. Stable manure is a favorite breeding medium for flies and should be stored in well-drained receptacles that are as nearly fly-tight as possible. A concrete floor will make it impossible for the larvae to pupate in the ground. Storage of manure on a slotted platform above a concrete floor covered with a few inches of water, will cause the downward burrowing larvae to drown. Compacting of manure raises its temperature and kills fly maggots as well as intestinal parasites. The use of insecticides for the destruction of fly maggots is not an efficient measure because of the large quantities of organic matter in the manure, but a solution of borax in water is useful for controlling the development of fly larvae in the surface.

yers of compacted manure. Adult flies are destroyed by residual sprays (see page 458).

The frequency of refuse collection varies with the season of the year. Garbage produced in greater bulk during the summer and ferments more rapidly in hot weather. This is also the time in which the breeding cycle of flies is shortest (about 10 days). It is, therefore, commonly collected at shorter intervals of time during the summer months (two to four days) than in winter (three to seven days). The garbage of hotels, restaurants, and markets is generally collected daily. Ash and rubbish collection is more frequent in winter than in summer.

**Disposal of Refuse.** In rural or sparsely settled communities the disposal of refuse is a simple matter. Garbage is fed to domestic animals, notably chickens and pigs. Failing this, it is either buried in field or garden or burned together with rubbish. Incineration is readily accomplished in suitable wire baskets. For large dwellings, isolated hotels, or camps, stone or brick incinerators are sometimes built. As shown in Figure 42-1, A, the damp refuse is thrown onto the drying

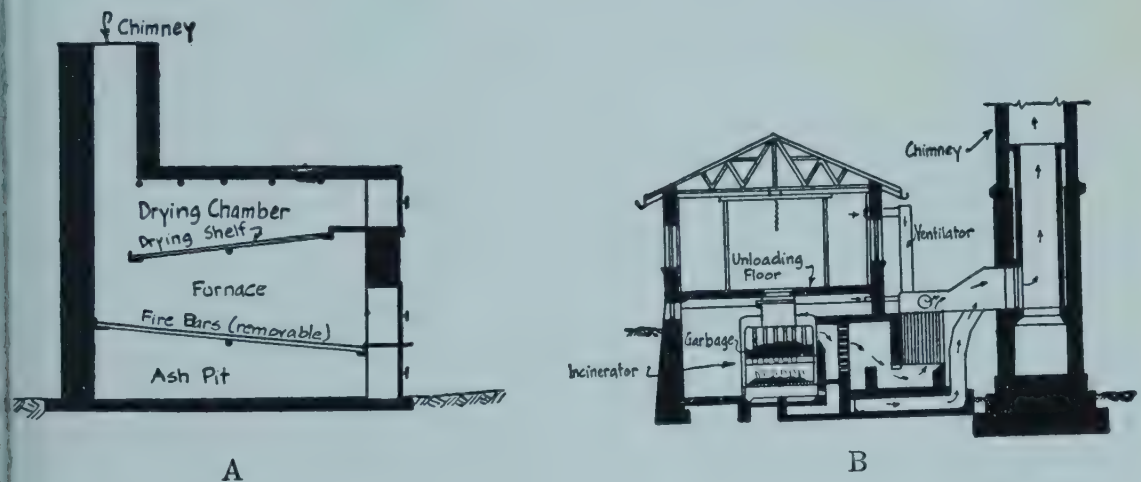


Fig. 42-1. Incinerators.

*A*, destructor suitable for camps, isolated dwellings, and small communities; *B*, cross section of a Decarie incinerator.

shelf of this incinerator, whence it slides or is pushed into the fire. If fly proof, this pattern may be used for the incineration of feces. In temporary camps the refuse can either be buried, or burned in open pits lined with rubble. In the circular rock pile crematory, the fire is built in one quadrant and the solid wastes are thrown into it. A central pile of rocks assists in creating a draft and offers a large surface for the evaporation of liquids which are poured into neighboring quadrants. When fuel is scarce and stones few, the Caldwell or English crematory can be used. It consists of a trench 10 feet long and 1 foot wide. It slopes from the surface at either end to the center where it is about 15 inches deep. A barrel is placed over the deep portion and a chimney of clay, earth, or sand properly tamped is built around it. A fire is made in the pit and the barrel is burned out, after which the solid cone of earth remains. Fuel and garbage are dropped through the chimney. The leeward opening is closed and a bed of tin cans is provided to take the place of a grate.



In urban communities refuse disposal becomes an important and sometimes vexing sanitary problem. A number of different methods are in use, as illustrated in Table 42-1. Composting of garbage and other refuse for conversion into fertilizer has not established itself in American practice.

Table 42-1. Methods of municipal refuse disposal

DUMPING AT SEA	SANITARY FILL	INCINERATION	FEEDING	REDUCTION	GRINDING
Garbage	Garbage	Garbage	Garbage	Garbage	Garbage
Animals	Ashes	Animals		Animals	
Ashes	Rubbish	Rubbish			
Rubbish	Street	Excreta			
Excreta	sweepings	Street			
Street		sweepings			
sweepings					

The choice of the system of disposal depends upon local conditions and must be decided by economic as well as sanitary considerations. Reasonable sanitation at a reasonable cost is the most that can be expected.

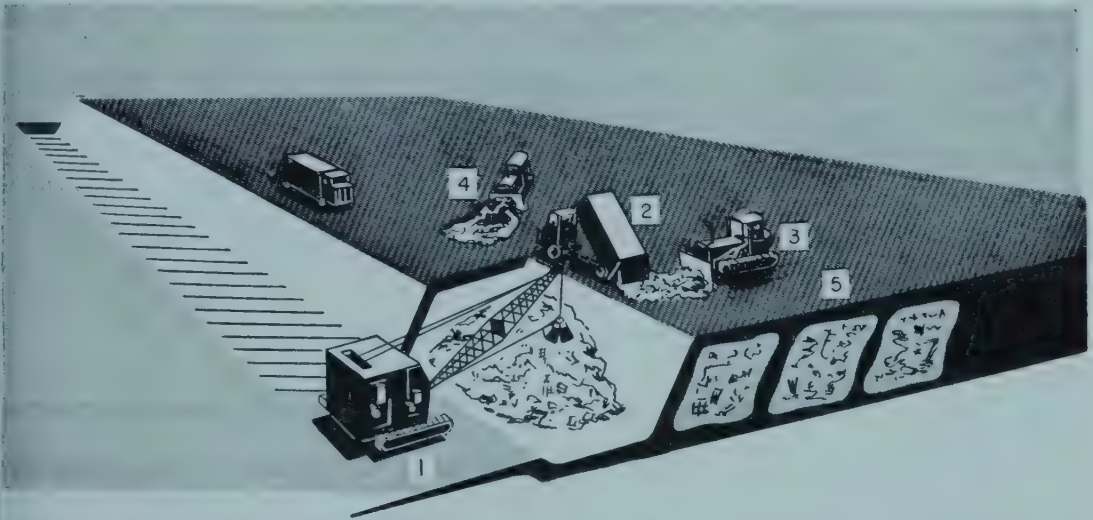
DUMPING AT SEA. In many seacoast towns, some of the municipal refuse, particularly garbage, is disposed of by placing it in scows that are towed out to sea and dumped. It is probably the cheapest method of refuse disposal, but may result in the ultimate stranding of sometimes putrid waste materials along the water-line of beaches and banks. Dumping of refuse into inland waters is no longer countenanced.

SANITARY FILL. Some of the refuse materials, notably ashes, are well suited for filling low-lying lands, abandoned clay pits and tidal marshes. Many communities have made profitable use of this method for the disposal of their mineral, non-putrefying wastes, and large tracts of so-called "made land" have thus been created. The only objection to this method is the blowing about of fine ash dust during windy weather. In the "sanitary fill" the method is expanded to include all of the refuse produced by the community.

If, as shown in Figure 42-2, the mixed refuse is properly placed, compacted, and covered, fermentation cells are created in which the temperature at the three-foot level rises to 130 to 150° F in about four days, remains at this magnitude up to about 60 days, and returns to normal in just under a year. To be successful, the fill must be kept less than six feet deep, the area normally required annually being three quarters of an acre to an acre and a half for 10,000 people. A well-compacted fill will settle from 25 to 40 per cent in the course of time. It will not give rise to odors or harbor rats and insects. Fires will not be produced spontaneously, but the hazard of their being set must be guarded against. Dump fires will smolder for years, producing acrid smoke and foul stenches that are carried long distances by the winds. Unlike the selected fill of inert refuse, areas that have been devoted to sanitary-fill operations cannot be developed as building sites for many years, but they can serve as parks and playgrounds almost as soon as they are completed.

INCINERATION. Incineration is the destruction of wastes by fire. The mixed refuse of cities and towns contains much combustible material and is readily dis-

posed of by incineration. In the United States it is customary to exclude all or most of the ashes, although the latter sometimes contain as much as 30 per cent of unburned coal. Ashes, however, are large in bulk and increase the operating difficulties of incinerator plants.



From Recommended Wartime Refuse Disposal Practice, U. S. Public Health Service, 1942.

Fig. 42-2. Sanitary fill operation on level ground.

1, dragline excavates trench; 2, truck discharges mixed refuse; 3, bulldozer places and compacts refuse; 4, cover material from trench is placed over refuse by bulldozer; 5, finished fill is impacted by trucks and bulldozer.

From the sanitary standpoint incineration affords an excellent method of refuse destruction, because the solids remaining after incineration are stable materials that can be used to fill lands adjacent to the incinerator. In order to prevent flours from the flue gases in the vicinity of incinerator plants, the temperature of the gases must be raised above  $1250^{\circ}\text{F}$ . Auxiliary fuel is frequently required to start the furnace. The steam generated by incineration can sometimes be usefully employed in operating the plant equipment and producing electric power, but steam generation requires incinerator temperatures of  $1800^{\circ}\text{F}$  or more.

Most incineration plants possess patented features that are intended to make them more economical or to secure speedier or surer operation. In some plants the refuse is first dried or heated before passing onto the incineration grates; in others it is deposited directly in the furnace. The hourly amount of mixed refuse burned varies from 50 to 80 pounds per square foot of grate area. The ashes produced equal from 15 to 50 per cent of the material burned. Incinerators are sometimes built into apartment buildings and residences, a chute carrying the wastes into the furnace (see Fig. 42-1, B).

**GRINDING.** The employment of sewers for the water-carriage of garbage from kitchens and markets is a logical expansion of this transportation system for household and industrial wastes. The garbage must be comminuted before it is discharged into the sewers. Otherwise it will cause stoppages. Individual household grinding units, or central grinding stations are provided for this purpose. The increased load of putrescible matter received by the sewage treatment and disposal



works must be given due consideration. The discharge of excreta into sewers is discussed in Chapter 41.

**Management.** The sanitary collection and disposal of refuse is a proper governmental function justifiable under the police power. In many small communities, however, refuse disposal continues to be undertaken by private enterprise without systematic governmental supervision. In some of the larger communities both the collection and disposal are entirely in the hands of the local authorities. In others the refuse is collected by the municipality but disposed of by private parties. In still others collection as well as disposal is contracted for. It is possible to obtain satisfactory results both with the municipal system and the contract system, but the latter is generally the more economical one. Salvaging operations for the recovery of paper, rags, bottles, and cans are sometimes included in the disposal of municipal refuse.

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## Section Eight

# METHODOLOGY

## 43

### EPIDEMIOLOGY

**Introduction.** Epidemic is a very old word, dating back at least to the third century, B. C. in the writings of Hippocrates. Epidemiology as a field of medical science is a concept which has been gradually formulated during the past century. By derivation, it is concerned with the explanation of epidemics of disease in human populations. While this definition still obtains in part, with the advance of biologic and medical science, usage of the term epidemiology has become more inclusive. An epidemic is commonly a sudden increase in the prevalence of a disease which is more or less constantly present, or endemic, in a community. To explain the sudden increase it is necessary to understand the factors and conditions which determine the usual or interepidemic levels of prevalence and the characteristic distribution which the disease ordinarily manifests in human population.

The widening horizon of the biological universe has extended use of the term epidemiology to the study of disease in animal populations and plant life. Although "epizootic" and "epizootic" have been used by veterinarians to describe the level of prevalence of diseases in animal populations, it is now considered good usage to refer to the epidemiology of cattle plague or of foot and mouth disease. While it is etymologically correct to use "epiphytic" to refer to an outbreak of infectious disease in plants, a modern plant pathologist may prefer to describe his observations on the stem rust of wheat under the title of epidemiology. Such usages are justified by the derivation of the word epidemic, which literally translated from the Greek means "upon the population." The population may be composed of people, animals, birds, fish, plants, or whatnot. Moreover, while in its early history epidemiology was largely concerned with infectious diseases, it has been found profitable to make a similar approach to the understanding of diseases of unknown origin, conditions due to nutritional deficiencies, to senescence, to abnormal cell growth, and even to casualties caused by physical or chemical agents, accidents, etc. Thus, usage has extended the meaning of epidemiology beyond its original limits to designate not merely the doctrine of epidemics but a science of broader scope in relation to the mass-phenomena of diseases in their usual as well as their epidemic occurrences. The subject is pursued here with a homocentric bias, since the concern is primarily with human welfare. For present purposes, therefore, *epidemiology is defined as that field of medical science which is concerned with the relationships of the various factors and conditions which determine the frequencies and distributions of an infectious process, a disease, or a physiological change in a human community.* It seeks to advance rational conceptual schemes of causation of the various ills that afflict mankind medically speaking. To the extent that this body of knowledge is advanced and valid, it becomes possible for appro-



priate community agencies to take effective measures directed toward prevention, control or eradication. As defined the field is a broad one.

Consideration of the principles and methods of epidemiology can be developed with advantage if the discussion is limited at first to the infectious diseases. In previous chapters, infectious diseases have been individually treated. For each there has been presented some account of the identifying clinical syndrome, the more important attributes of the causative agent, and the manner of its occurrence in human populations in terms of its geographical and seasonal distribution, selectivity for various population groupings, such as sex, age, race, and occupation, endemic and epidemic prevalence, etc. It has become apparent that each has a characteristic epidemiological pattern as well as clinical pattern. There is an endless variety and it would appear on the surface that each is a law unto itself. Yet there are generalizations which can be applied to the behavior of all infectious diseases in human populations. The conceptual scheme upon which these generalizations depend was comprehensively formulated by Theobald Smith in 1934.

*Infectious disease is a manifestation of parasitism.* Acceptance of this concept marked an important transition. The medical explanation of disease broadened to become a biologic one. Infection was no longer set apart as a phenomenon peculiarly within the province of human medicine but was viewed in its natural relationships as an expression of the eternal struggle of living things for food by predation or parasitism, for shelter and for propagation of their kind. More particularly, it is the reaction between one of the higher forms of life to the invasion of its tissues by some species of microparasite. This conception carries with it implications that are fundamental and far-reaching. It affords a framework or pattern into which endless scattered observations can be fitted. Explanation of epidemics can then be sought in host-parasite relationships and the environmental factors which modify them.

As a result of centuries of host wanderings, mutation and selective adaptation, certain worms, protozoa, fungi, bacteria, rickettsia, and viruses have in some degree become established in the biologic orbit of man, and are responsible for some of his ills. Their potentialities range from those which only rarely and inadvertently invade his tissues to cause an occasional sporadic case of a rare disease, to those which are dependent upon human tissues for their continuous propagation, sometimes giving rise to epidemics which decimate tribes or nations and change the course of history. The importance of each parasite species to man has been determined by a few biological conditions to which only brief reference can be made.

Man may be an obligate, a principal or an occasional host species, according to the degree of success which a particular species of parasite has in passing through four critical stages in relationship to him. A micro-organism may become completely dependent upon man for its survival if it is continuously successful (1) in finding entrance into his body through its proper portal of entry, whether it be the mucous membrane of the respiratory, the alimentary or the genito-urinary tracts, or the skin by means of trauma or insect bite; (2) in reaching the particular organ, tissue or cells in which the nutritive conditions are most favorable for multiplication; (3) in making an exit from the body in excretions, secretions, or by blood-sucking arthropods; (4) in surviving under the conditions of the external

environment, or in an arthropod vector, a sufficient time to reach a new susceptible host. To the extent that it is unsuccessful in continuously maintaining progressive passage through these four critical stages in human populations and their environment it must be able to utilize other host species or survival mechanisms. Thus, one of the first requisites of a rational explanation of the behavior of an infectious disease in a human population is to understand *to what extent man as a host shares responsibility for the continuous propagation of the causative microparasite with other species—animal, bird or arthropod.*

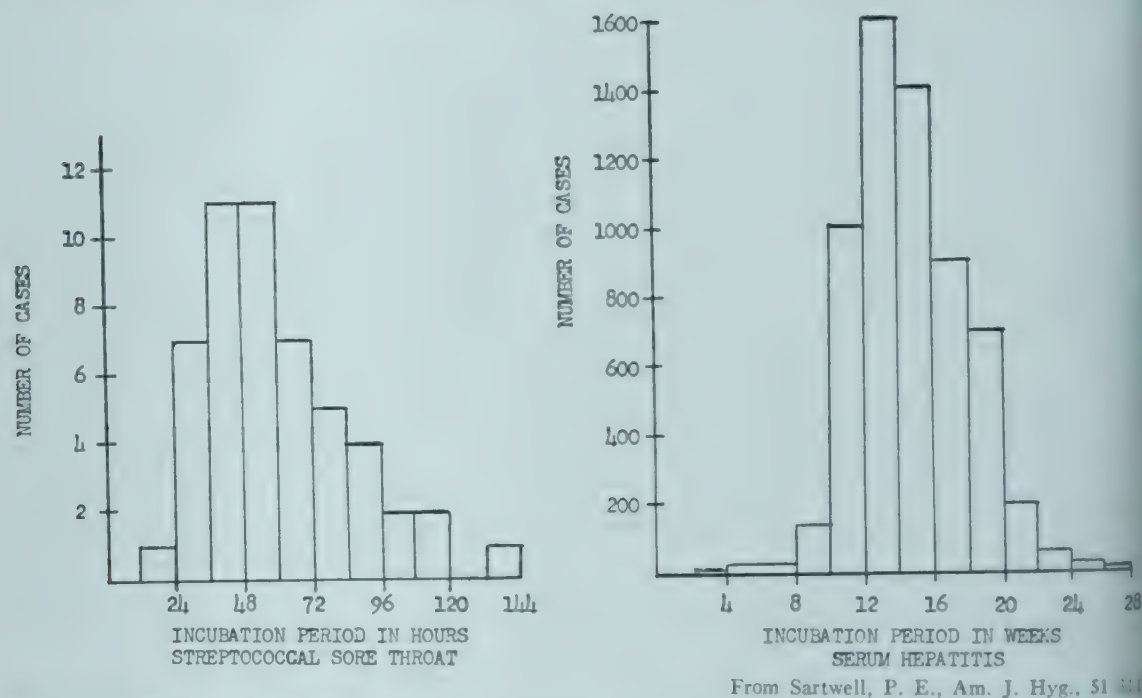
**Incubation Period.** The first stage in infection is the incubation period, that is, the interval of time from primary invasion through skin or mucous membrane to the onset of symptoms of the disease. Its length depends upon the peculiarities of each particular host-parasite relationship. It is extremely short, a matter of hours, when the symptoms are due to preformed growth products or to large numbers of micro-organisms which have already had opportunity to multiply in the ingested foodstuff, as in some *Salmonella* infections. It is short, a matter of days, when the microparasite has more or less direct access to the tissue in which primary multiplication takes place, as in certain air-borne infections with microparasites which multiply in the epithelial cells lining the respiratory tract, as in influenza. It is longer in those infections in which the microparasite is unable to multiply at the site of entrance into the body but must make its way through lymph channels to regional lymph nodes by the lymphatics to the blood stream, in a stepwise multiplication and invasion, bypassing the defensive barriers and the phagocytic activity of the host tissues, ultimately gaining admission to the general circulation and affecting the organs or tissue cells for which it has a predilection and in which it can multiply, as with such diseases as typhoid. Thus, the incubation period may be a matter of hours, days, weeks or even months, but for any particular disease its length is relatively constant and predictable.

However, as with any other measurable biologic attribute, *the incubation period of a specific infectious disease manifests a constant range of variation.* Most frequency distributions of incubation periods bear a resemblance to the normal curve with slight skewness, rising more abruptly on the short side of the mean; examples are shown in Figure 43-1. As Sartwell (1950) points out, the degree of variation in relation to the magnitude of the mean has a constant statistical pattern, no matter whether the unit of time be hours, days, weeks or months. The range of the incubation period is an important epidemiological characteristic for each disease.

**Host Reaction.** Multiplication of the microparasite within the host organism up to the threshold point at which it disturbs the physiological state gives rise to the symptoms and signs of illness by which the disease is recognized. The second critical stage in the host-parasite relationship mentioned above ensues. The host reaction or, properly speaking, the host-parasite interaction may vary greatly, both in severity and duration. A case of an infectious disease is a host reaction of sufficiently characteristic intensity and duration to permit clinical diagnosis. Reactions which are less intense and of shorter duration are called *abortive* or *suspected* cases, the pattern being too definitive or protean in nature to permit clinical diagnosis, except in association with *frank* cases. When the subjective and objective symptoms are so slight as to pass unnoticed, the host is said to suffer an *inapparent* infection. Infections which are below the threshold of clinical recognition are



grouped together as *subclinical*. They can be identified only by such procedures as cultural recovery of the infecting micro-organism from the host's tissues, as, for example, by nose and throat cultures for diphtheria bacilli; change in the response of the skin to specific antigenic material, as in the tuberculin test; or change in a serologic reaction from a negative to a positive, as in a serum neutralization test



From Sartwell, P. E., Am. J. Hyg., 51: 311

Fig. 43-1. Frequency distributions of incubation periods. Left, epidemic of food-borne streptococcal sore throat (scarlet fever) (in hours); right, a series of cases of serum hepatitis following administration of icterogenic lots of yellow fever vaccine (in weeks).

with the virus of influenza. It is at least theoretically possible that an infection may occur without demonstrable reaction on the part of the host, i.e., a symbiotic or a saprophytic relationship, but there is a difference of opinion as to whether the word infection should be used to describe such a condition.

**Infectious Period.** In clinical medicine, interest is centered upon a patient during the period that he or she is more or less incapacitated by the disturbance of physiologic functions caused by the invasion of a pathogenic micro-organism, i.e., from the onset of symptoms to clinical recovery or to a fatal issue. In epidemiology, interest must be broadened to include the whole duration of the host-parasite relationship, i.e., from the time of the infective exposure until the microparasite is suppressed or eliminated from the host's body. This includes the incubation period, clinical manifestation, convalescence, latent periods, relapses, to death or final elimination of the microparasite from the body. Of particular importance is the *infectious period*, the time or times during which the *microparasite progeny* are making an exit or are potentially available for transfer to a new host.

**Carriers and Inapparent Infections.** As early as 1890, Escherich noted that the infectious period of diphtheria was not necessarily coincident with the clinical course but that diphtheria bacilli might persist in the throats of patients during convalescence. In 1892, Guttman, Rommelaere and Simonds noted that cholera

prios might be recovered from the feces during convalescence. Credit probably longs to Koch (Winslow, 1943) for grasping the important fact that cases which could be clinically diagnosed were not alone responsible for the spread of contagious diseases. In his studies of cholera in Germany, during the winter of 1892-93, he noted that some cases were so mild that they escaped recognition, and indeed could be detected only with the aid of bacteriological investigation. The term carrier thus includes two classes. First, there are those who are about to have or have already had a clinical attack; they are designated as *incubatory*, *convalescent* or *chronic* carriers. Second, there are those who are suffering from a subclinical or asymptomatic infection, the so-called *healthy* carriers. It is important to distinguish between these two classes; for the purpose of this discussion, the second class of carriers will be included in the designation *subclinical* or *inapparent* infections.

**Pathogenicity.** The characteristics of the clinical reaction and the ultimate issue of the infectious process is determined by the balance between the devices of aggression of the specific species of microparasites and the mechanisms of defense of the host species, capacities for both of which are genetically transmitted. The attributes of the parasite which determine the outcome of the reaction are described by such words as infectivity, pathogenicity, virulence, antigenic power. These attributes, however, cannot be considered apart from those of the host which are opposed. These host attributes are described by such words as susceptibility and resistance. Resistance, in turn, is broken down into such concepts as genetic resistance, maternal immunity, naturally and artificially acquired immunity, antibody response, interference phenomenon, etc. These attributes, both of the microparasitic species and of the human host, are mutually relative and subject potentially to all degrees of quantitative variation, not only as between different species of microparasites and different broad population groups, but also between strains of the same microparasitic species and individuals in the same general group. For the sake of simplicity, in this discussion they will be included under a broad definition of the term pathogenicity.

In this sense, the *pathogenicity of a given microparasitic species for a human host population cannot be measured experimentally on animals*. It is indicated only by observations on the experience of human beings exposed to this particular infection under natural conditions. To the extent that infection may result in recovery or death, pathogenicity is roughly indicated by the proportion of attacks which are fatal. Stated in different words, it is a ratio between cases and deaths (usually the percentage of cases which are fatal) or the *case fatality ratio* of a disease. This ratio, however, may be affected in a considerable measure by non-specific conditions which affect the host population, such as starvation, lack of proper medical care, secondary invasion by other micro-organisms, or other factors.

To the extent that the infection may result in a residual of impaired function, pathogenicity may be indicated by the proportion of cases which exhibit paralysis or other defect. Finally, and more important, it is possible with many infectious diseases to estimate the proportion of the total number of individuals infected with a particular microparasite who manifest a characteristic clinical reaction, i.e., the ratio of subclinical to clinical infections. For example, in measles it is of the order 1:19; in diphtheria, in the age group 10 to 14, at the time of a particular study, it was 15:1. Such ratios vary not only with the species of microparasites but fre-



quently with different strains or types of the same species, as with streptococci and pneumococci.

**Successful Parasitism.** Successful adaptation of a species of microparasite to the human host does not imply a high order of pathogenicity. Rather the contrary is true. Success for a parasite, as for any other living organisms, can only be measured by the size of the population of its kind and its ability to survive and maintain these numbers in a constantly changing natural universe. There is no advantage if its host sickens and dies, since dissemination of its progeny accordingly becomes limited and soon ceases. The opportunities for scatter and chance of productive contact are increased in proportion to the length of time it can continue to multiply and find easy egress in large numbers from a host which is ambulatory and gregarious. Accordingly, a high case-fatality ratio may be a disadvantage to survival of a parasitic agent. Conversely, a low ratio of clinical to subclinical infections and a long duration of the infectious period tends to insure wide dissemination. The microparasites best adapted for survival are those which cause infection with the least inconvenience and injury to the host species, and create only a low grade immunity of short duration. A notable exception to this generalization is canine rabies.

Those infectious diseases which are continuously maintained by person-to-person transfer, in other words the *contagious diseases*, are caused by microscopic species which have been successful in their relationships with the human host. Those diseases which are not directly transmissible from man to man, or transmissible only occasionally under unusual circumstances, as in pneumonic plague (*noncontagious diseases*), are caused by microparasitic species which are unsuccessful in their relationships with the human host. In man, they represent aberrant parasitism. They succeed occasionally in making effective contact, multiplying and causing human disease but the pathology which they generate does not permit their exit from the body in sufficient numbers to make effective contact with a new human host. They must be maintained by and come from extrahuman sources. They have been successful in adapting themselves to survival in some host species, animal, bird or arthropod (as in human plague or tularemia); or by an alternation of human species by the intermediation of a vector (as in malaria); or they have found conditions under which they can survive, multiply and propagate in the environment outside the human body as, for example, such fungi as *Coccidioides immitis*. Obviously, the factors and conditions which determine the frequency and distribution of the first class of diseases are relatively simple and much more easily understood than are those that relate to the latter classes.

**The Dynamics of Contagious Disease.** The forces which create the dynamic phenomena of contagious disease are, in the ultimate analysis, population pressures, i.e., the innate impulse of living micro-organisms to multiply and survive by parasitism upon homo sapiens, and the efforts of this host to preserve its own integrity. The balance between these two forces is constantly fluctuating, just as are the interactions between all living species. When the balance is relatively stable, it is manifested by an *endemic* prevalence. When the balance is subject to sudden or violent disturbance it is manifested by *epidemics*. If the balance is in favor of the host, the disease shows a downward trend and tends to disappear. If the balance is in favor of the microparasite, the disease tends to increase in prevalence.

To represent these phenomena, and to facilitate reasoning with regard to them, is necessary to use quantitative indices. The conventional rates and ratios which are commonly used for this purpose are described in detail in the succeeding chapters. Reference here is made particularly to: (1) case, attack or morbidity rates; (2) mortality rates; (3) prevalence rates. Indirectly they express the relationship of the number of the parasitic population (numerator) to the number of the host population (denominator). The denominator (the number of individuals of the host population who are at risk of attack at any particular time or during any particular calendar period) can, in many situations, be counted or estimated with considerable accuracy. The numerator (number of parasitic micro-organisms in the same universe of time, place and persons) can only be indirectly represented. It is correlated in a rough way with the number of deaths, or cases, or infections caused by a specific microparasitic population. It must be constantly borne in mind that these quantitative expressions are not measurements but are indices of these biologic phenomena.

To represent the shifts in balance or changes in equilibrium between a micro-parasite and the host population, the expression of choice is, ordinarily, an attack rate based upon cases by date of report, onset, discovery, or admission to a clinic on successive days, weeks, months or years. If interest is limited to the frequency of the occurrence of such cases, and the population at risk is relatively constant during the period under consideration, it is unnecessary to calculate the rates. The time sequence of the number of cases reflects changes in the frequency with which the microparasite is spreading and gaining access to new susceptible individuals and, accordingly, the increase or decrease in the microparasitic population. This is well illustrated by the account which is given of the spread of measles (see measles, Chapter 1).

**Progressive or Contact Epidemics.** Frequently, the term epidemic refers only to a peak in the oscillating incidence of a disease more or less constantly present in a community. How great the increase in incidence must be before it is regarded as an epidemic is a matter of judgment, and is influenced by psychologic attitudes. The greater the fear of a disease, or the more unusual it is in a community, the smaller the increase needs to be to justify the use of the descriptive term. Many statistical devices have been suggested for making the definition more objective and precise (Rich and Terry, 1946), but no definition has yet received general sanction. Dependence is placed in general upon comparing the current incidence of a disease with its incidence in the past in the same population group and at the same time of the year. This expected number, or norm, is commonly expressed as a three-year or five-year median of reported cases. When current incidence exceeds this number, the disease shows the tendency, which if sustained and great enough, sooner or later merits the pronouncement of the presence of an epidemic.

Each contagious disease has a seasonal variation which follows a more or less regular pattern, reaching its maximal distribution about the same time each calendar year when conditions are most favorable for transmission. Each is subject also to an interannual variation, or secular trend, which may show slight or wide fluctuation, and some of which under limited conditions exhibit a more or less regular periodicity. For the common contagious diseases, most of the factors which affect the fluctuation in the rate of transmission are known and can be enumerated.



**CHANGES IN THE BIOLOGY OF THE MICROPARASITE.** Some species of microparasite are relatively stable in their biological attributes and show little capacity to vary toward higher or lower pathogenicity. Such, for example, is the case with the virus of measles. At the other extreme are species which are relatively unstable and show considerable ability to vary. Such, for example, is the case with the virus of influenza, which includes not only at least two immunologically distinct types (A and B) but which shows a considerable antigenic variability within each type. Type A is not immunologically homogeneous but includes a large number of strains which exhibit minor immunologic differences when measured by laboratory procedures. Between these two extreme examples are all gradations in the potentialities for strain variation. In general, those strains tend to propagate which are selectively best adapted to multiplication and survival in a human population at a particular time.

**GROUP OR HERD SUSCEPTIBILITY.** The human community is made up of a number of individuals who vary not only in their genetic capacity to react but nearly always in previous experience with the predominant strains of a particular species of microparasite or its close relatives. Some individuals have acquired a complete immunity, some a partial immunity, some none. The proportion of a population at any one time which has little or no immunity determines the theoretical level of a community, group or herd susceptibility for a particular contagious disease. If such a disease is commonly prevalent in a community, the proportion is a constantly changing one as susceptibles are infected, develop immunity and recover. If the immunity conferred by either subclinical or clinical infection is durable, then the group susceptibility decreases with advancing age as more and more of the population have had experience with this antigen, and the age distribution of cases consequently is that of a children's disease. If the immunity conferred is temporary, as with some acute respiratory infections, such as influenza, the same individual may be reinfected after a short interval, and consequently the disease may attack all ages, adults and old people, as well as infants and children. Thus, for each of the common contagious diseases there is a characteristic age distribution from which inferences may be drawn with regard to past experience and durability of specific immunity.

By means of a skin test or serological examination of a representative sample of persons, it is possible with some to establish the immunity status of a community. The age distribution of immunity may give information with regard to the time at which the disease was last present in the community. A good example of this type of observation is the report of Paul and Riordan (1950) on their findings with regard to the Lansing strain of poliomyelitis virus in sera from Alaskan Eskimos. In the belief that Eskimos have less exposure to poliomyelitis than do most other populations, serum samples from Eskimos living on the north coast of Alaska were collected and studied. Particular attention was paid to the presence or absence of neutralizing antibodies to the Lansing strain of poliomyelitis virus. Poliomyelitis is known to have been present along this north coast in 1930, but among the scanty and unreliable records available there is no note of its occurrence since that date. The neutralizing antibody test of this Lansing strain of poliomyelitis virus revealed that nearly all natives who were tested from the two villages, and who were below the age of 20 failed to have antibodies; whereas

in those who were age 20 and above about 80 per cent had these antibodies in their sera. The evidence suggested that there had been no exposure or infection to the causative strain in this remote community since 1930.

**POPULATION DENSITY AND MOVEMENT.** The critical level of susceptibility ("epidemic potential") required for the rapid passage or epidemic spread of a contagious agent varies from community to community, and even in the same community, at different times, depending upon population density and other factors. The degree of crowding or dispersal of a population may be indicated in many ways; the most common is the classification into urban and rural populations. Quantitative estimates are sometimes made of the number of persons per square mile, the number of individuals per house, or the number of persons per room. These expressions are intended to convey in a rough way an idea of the frequency with which one individual may meet or have contact with another individual under conditions which would permit the passage of infectious agents from one to the other. The association of the unusual prevalence of contagious diseases with crowding, in communities, in institutions, in jails, on ships, in barracks, in refugee camps, etc., is a very old one.

Opportunity for the dissemination of microparasites is obviously facilitated by the amount of population movement, travel and flow of people through a community. In isolated small communities, with a small natural turnover in population by births and deaths, many of the common communicable diseases are unable to maintain themselves over long periods of time; because of acquired immunity they tend to die out and must be reintroduced. Under modern conditions of travel, however, such communities are encountered only in the most remote parts of the world. Today there is a constant flow of people into and out of most communities. A sudden increase in the incidence of a disease may be precipitated by the arrival of a large number of susceptible individuals such as refugees, immigrants or recruits.

**HABITS OF LIVING AT HOME AND IN COMMUNITIES.** The customs and habits of the people are obviously important in affording opportunities for transmission. For respiratory diseases this relates to customs with regard to uncontrolled coughing, spitting, and sneezing. For enteric infections it relates to the habits of fecal disposal, hand washing, etc. For venereal diseases it relates to the habits with regard to promiscuous sexual intercourse. The general concept is expressed in terms of the level of household cleanliness and personal hygiene. In communal living, the potentialities of common water, milk and food supplies and of methods of sewage and refuse disposal for the dissemination of pathogenic microparasites are well known. Indeed, the downward trend on many of the contagious diseases, particularly of the enteric group, during the past half century is the result of sanitary measures designed to reduce to a minimum the stream of fecal micro-organisms through the human alimentary tract by common vehicles.

**CLIMATIC FACTORS.** Temperature, humidity, rainfall, and sunlight may influence the equilibrium between the microparasite and host population in a number of different ways. Such factors may directly influence survival of a microparasite in the external environment on objects, in soil, in dust, water, and in food. They may thus facilitate or retard the passage of the microparasite from one host to the next. On the other hand, these factors may affect the resistance or immunity of the host population. Less is known about the latter effect, but there is some reason



to believe that resistance to certain microparasites may be indirectly affected by changes which take place with season, and more particularly with sudden extreme changes in body temperature.

It is apparent from this brief summary that the host-parasite balance is determined by large numbers of factors and conditions, and is the resultant of a complex biological situation. While to a considerable degree *these factors and conditions may be recognized, described, and enumerated, their relative importance varies with each contagious disease and with local circumstances.* To assess their relative importance for a particular disease, in relation to a definite locality, population and time, is one of the principal objectives of an epidemiological investigation, because upon such knowledge effective control depends.

**Experimental Epidemiology.** One approach to the elucidation of these relationships is through observations made upon artificially induced epidemics in experimental animal colonies. Notable particularly in this connection are the studies of Webster and his associates (1932, 1946) on *Salmonella*, *Pasteurella*, pneumococcus and Friedlander bacillus infections, and the studies by Topley and his associates (Topley, 1942; Greenwood and others, 1936) on *Salmonella*, *Pasteurella* and ectromelia virus infections. These studies are too extensive to permit detailed review; it will be useful perhaps to comment briefly upon the methods used and the knowledge gained.

The general procedure was to assemble uninfected animals in unit cages, the arrangement of which could be altered to simulate a community of any desired size. A constant regime of cleaning and feeding was established, and appropriate measures taken to prevent the introduction of extraneous, pathogenic micro-organisms. An epidemic was started by introducing into an uninfected animal colony a certain number of animals infected with the microparasite selected for the experiment. The course of the subsequent epidemic was indicated by the occurrence of specific deaths, proved by necropsy and culture. *Effort was made to hold all of the important factors and conditions constant except the one under examination and to note the effect this variable had upon the course of an artificially produced epidemic.*

It became evident very early in this work that a constant genetic stock of experimental animals was fundamental to control of the host variable. As had long been known to the plant pathologists, it was found possible within certain limits by selective mating to breed out lines that were relatively susceptible to infection with a particular micro-organism, such as *S. enteriditis*, the cause of mouse typhoid. It was demonstrated, for example, that there may be selected promptly from a hybrid stock of mice, of which 40 or 50 per cent die, lines in which as high as 95 per cent and as low as 15 per cent succumb following a standard dose of *S. enteriditis*. This afforded experimental evidence of the importance of innate differences in resistance genetically transmitted in human families, lines of descent, races, to a particular microparasite, a phenomenon well illustrated by the differences in the host reaction of the white and Negro race to infection with *Mycobacterium tuberculosis*.

The possible importance of nutrition of the host to natural resistance to infection was appreciated. If a diet were so poor in quality or quantity as to bring about a state of debility, experimental animals whose lives were already in jeopardy

om the consequences of produced deficiency would have a higher death rate an well-nourished animals if subjected to the added insult of infection. Obviously, it was desirable to hold this factor constant by providing a uniform and well-balanced diet. It was noted, however, that a diet which was well balanced for normal growth and development, was not necessarily well balanced in its effects upon host resistance to infection with a specific micro-organism. This question has been explored extensively by many investigators in relation to various infections experimentally produced in animals. It has been demonstrated that specific "natural resistance" can be influenced by nutrition when the host stock is genetically heterogeneous and the pathogenic population to which it is exposed is heterologous in the sense that it contains an array of variation in terms of capacity to produce disease (Schneider, 1951). These studies have advanced the understanding of underlying mechanisms implied in the terms resistance and susceptibility, but diet was of very limited importance as one of the variables affecting the results of experimental epidemics produced by *Salmonella enteritidis*.

The variability in the biologic potentialities of the strains of infecting micro-organisms employed received considerable attention. A theory has been advanced by certain speculative epidemiologists that the rise and fall of an epidemic, such as the epidemic of influenza, are principally, if not wholly, due to a progressive increase and decrease, respectively, in pathogenicity of the specific agent, the increase being brought about by the rapid passage of the infecting agent in human beings during the early part of an epidemic and the decrease occurring because the infecting agent is subjected as the epidemic progresses to more resistance and less frequent passage as the result of increasing immunity in the host population. To test this theory, methods were devised by Webster for measuring the pathogenicity of a specific strain of micro-organism for groups of mice by administering a fixed dosage. Sample cultures were obtained from animals dying at various times during artificially produced epidemics. Comparative titrations were made on strains from epidemics of pasteurellosis in rabbits, chickens and mice. Similar titrations of two serologic types were made during the course of mouse typhoid infections in mouse populations. A total of 300 to 400 titrations were made under many conditions to test the theory of fluctuating pathogenicity. "The results were invariably negative and showed a constancy and fixity of disease-producing power of a given strain of organisms under all conditions of natural infection. . . ."

From his experience with experimental epidemiology, Webster was inclined to believe that in all instances changes in biologic potentialities of specific micro-parasitic species are of little or no importance in determining the rise and fall of epidemic waves. While this may be true for many parasitic species, there are some which are more unstable and have a greater capacity for selective variation in pathogenicity (Burnet, 1951).

Other highly suggestive experiments were conducted by Webster and associates. In one series of studies it was demonstrated that, when infected animals were introduced in a closed universe of susceptible animals, the ensuing epidemic quickly subsided as susceptibles died or became immune, although some escaped infection. An epidemic started in this manner could be maintained in an open universe if sufficient susceptible recruits were added at regular intervals. If the conditions were held relatively constant, the balance between the microparasites and the host popu-



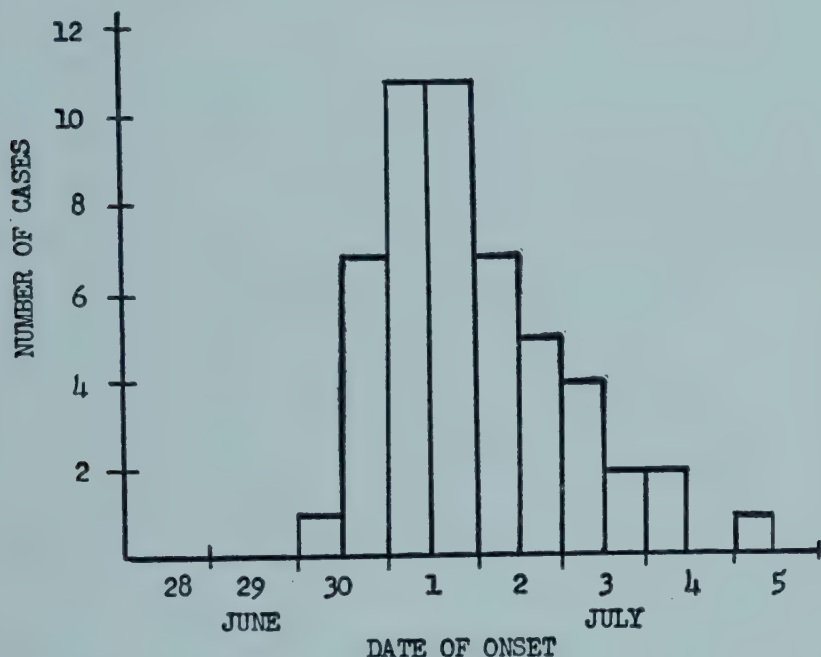
lation tended to reach a stabilized equilibrium. This was violently disturbed by a major change in the contact rate, which was accomplished by bringing a large number of animals previously dispersed in small single cages into a single colony in a large cage.

These and other experiments added support to some of the generalizations derived from experiences with epidemics in human populations under natural conditions. They emphasized particularly the accelerating effect upon incidence of an inflow of susceptibles into an infected community, and of aggregation of individuals into large groups (crowding) and per contra the dampening effect upon incidence of accumulation of immunes. *But the relative importance of each of these factors and conditions varies with the disease, its mode of transmission, the host relationships involved and the local circumstances.*

**Common Vehicle Epidemics.** When in a *relatively* short time interval there is an abrupt increase in the incidence of a disease previously absent or occurring only endemically, in a particular population group and environment, investigation of the causative conditions and factors may be simple. The word *relative* implies a standard of comparison. In this case the comparison is between the distribution of cases by time of onset and the range of variation of the incubation period of the particular disease involved. Thus, if a considerable proportion of the cases occur within the approximate time limits of variation of the incubation period, it can be assumed a priori that these individuals were exposed to infection at or about the same time. The microparasitic population has suddenly found an opportunity and a vehicle by which it can be disseminated more or less simultaneously through a group of individuals. A certain proportion of the exposed persons is susceptible, and to that extent they come down with subclinical or clinical attacks characteristic of the specific infectious agent. The problem is resolved by searching for the single factor, usually contaminated water or milk or some other food supply.

For example, in early July, 1934, an unusual number of cases of streptococcal sore throat were reported in a village in northern New York State. An investigation conducted by the district health officer developed the fact that the persons affected lived in widely separated parts of the village and that all had attended a church picnic about 1 P. M. on June 29. Of the 251 persons attending the picnic, 62 were found to have been attacked by streptococcal sore throat (scarlet fever). The distribution of 51 of these cases by date of onset is shown in Figure 43-2. It will be noted that all occurred within the time period of one to six days following the picnic. This is within the range of variation in the incubation period of streptococcal sore throat (see Fig. 43-1). The conclusion was inescapable that these individuals had been exposed to infection upon a common occasion. Three secondary cases occurred among 81 household contacts of picnic cases who did not themselves attend this gathering. Time intervals between the onsets of primary and secondary cases were 3, 13 and 16 days, respectively. The inquiry was then resolved into ascertaining the article of food or drink served upon this occasion which acted as the vehicle of dissemination. The menu included various kinds of sandwiches, baked beans, potato salad, potato chips, pickles, ice cream, several varieties of cake, lemonade, and coffee with cream. A careful history was taken of the items of food and drink consumed by each person known to have attended

e picnic. From these data were tabulated first a comparison of attack rates from reptococcal sore throat among those individuals: (a) who did not, and (b) who d partake of each item. This was checked by a reverse comparison of the proportion of persons who had consumed each item among those who: (a) had



g. 43-2. Distribution by date of onset of 51 cases of streptococcal sore throat (scarlet fever) in a common vehicle epidemic.

reptococcal sore throat, and (b) did not have streptococcal sore throat. These comparisons, together with collateral considerations of the method of preparation, opportunities for contamination and multiplication of hemolytic streptococci, led to the conclusion that the outbreak was probably due to either ice cream or potato salad, the evidence in favor of the potato salad as the vehicle being slightly more suggestive than that in favor of the ice cream.

It is to be noted that the common vehicle may be effective in dissemination on a single occasion, as is usually the case in food poisoning, or it may be effective over a period of time, as is frequently the case with water-borne outbreaks. The termination of the epidemic depends upon the interval during which the contamination of the vehicle persisted and was consumed, or upon the exhaustion of susceptibles, and the extent to which the particular disease is transmitted by contagion to secondary cases.

**Investigation of an Epidemic.** In undertaking such an investigation, it is desirable to have an orderly procedure. The following outline is suggested as applicable, in general, to such situations:

A. Preliminary analysis on the basis of the information available at the time the investigation is begun.

1. *Verify the diagnosis.* This may require only a brief review of the clinical findings, or may necessitate getting laboratory tests under way.

2. *Verify that an epidemic exists,* by comparing the incidence of the disease with its usual incidence in the community.



3. Orient the epidemic as to *time* by determining the chronological distribution of dates of onset (the epidemic curve).

4. Orient as to *place* by determining the geographical distribution of cases.

5. Orient as to *persons* by determining age, sex, race, and when possible, other characteristics of the cases; determine attack rates according to these characteristics.

6. On the basis of a rapid preliminary analysis of the selection of the disease as to time, place and persons, formulate tentative hypotheses to guide further investigations. Attempt to classify the epidemic as to mode of transmission as follows:

transmission by a	{	single exposure
common vehicle		continued exposure

propagated by	{	person-to-person spread
		arthropod vector
		animal reservoir

#### B. Further investigation and analysis:

7. Search for additional cases which may not have been recognized or reported.

8. Determine what additional information is necessary to answer any questions formulated and to test tentative hypotheses. Plan and conduct a detailed epidemiological investigation of all the cases (or of a representative sample of cases), using a suitable epidemiological case card. Arrange for any special investigations needed to establish collateral circumstances, using laboratory facilities, engineering and other expert consultation.

9. Analyze detailed data derived from case investigation, comparing attack rates among various pertinent groupings. Try to identify the group selected for attack and discover the common source or vehicle to which they were exposed, if any. Assemble results of collateral investigations.

10. Test various hypotheses which have been suggested, to ascertain which one is consistent with all the known facts. Base conclusions on all pertinent evidence, not relying upon any single distribution or circumstance by itself. If more than one hypothesis fits all the known facts, seek further evidence until the sum total of evidence is consistent with only one hypothesis. Formulate conclusions as to the source, mode of transmission and all other features of the epidemic which require explanation.

A report of the investigation of an epidemic may be organized along the lines of the outline given above. In addition, it should usually include a discussion of factors leading to the occurrence of the epidemic, an evaluation of the measures employed for its control, and recommendations for the prevention of similar episodes in the future.

**Dynamics of Noncontagious Infections.** Up to this point, for the sake of simplicity in discussion, attention has been principally focused upon infections transmissible directly from one human being to another, i.e., contagious infections.

as has been pointed out previously, some of the most devastating diseases of mankind are due to microparasites: (a) which can make exit from the human body only through intermediation of the bite of an arthropod vector, or (b) cannot make an effective exit, human infection being a terminal event in transmission. In the former situation, man may share responsibility for continued propagation of a microparasite with an arthropod vector in a transmission chain, as in the "louse-man-louse" propagation of epidemic typhus fever. In the latter situation, survival of the parasitic species is entirely independent of its relationship to man. Thus, *Rickettsi mooseri*, the cause of murine typhus, is continuously propagated in the Norway rat and related rodent populations through the mediation of rat ectoparasites, particularly the flea *Xenopsylla cheopis*; the principal transmission chain is "rat-flea-rat." The infection of man by this flea is an accident which is of no importance in the continuous passage of *R. mooseri*.

To understand and effectively interfere with the spread of such diseases in a human community, it is necessary to take into account not only the factors and conditions which affect the human host and the microparasitic populations, but those which affect the vector and extrahuman vertebrate host populations and their relationships to the microparasite on one hand and to man on the other. If only man and an arthropod vector are involved in propagation, the biological relationships are not too complex for quantitative expression and comprehension, as in malaria. The internal relationships of the malaria plasmodia to the human host and to the mosquito host are approximately the same everywhere. However, the living conditions of the population, the habits of the particular anopheline vector species with regard to breeding places, resting places, feeding habits and blood meals, etc., and the climatological factors which affect these two are eternally changing from one locality to another and make necessary careful malaria surveys precedent to well-directed measures of control. When, on the other hand, the microparasitic species is gregarious in its host relationships, both as regards vertebrates and arthropods, and at the same time capable of surviving for considerable periods of time in the external environment as, for example, with such micro-organisms as *P. tularensis*, the biological complex responsible for its continued propagation is exceedingly involved.

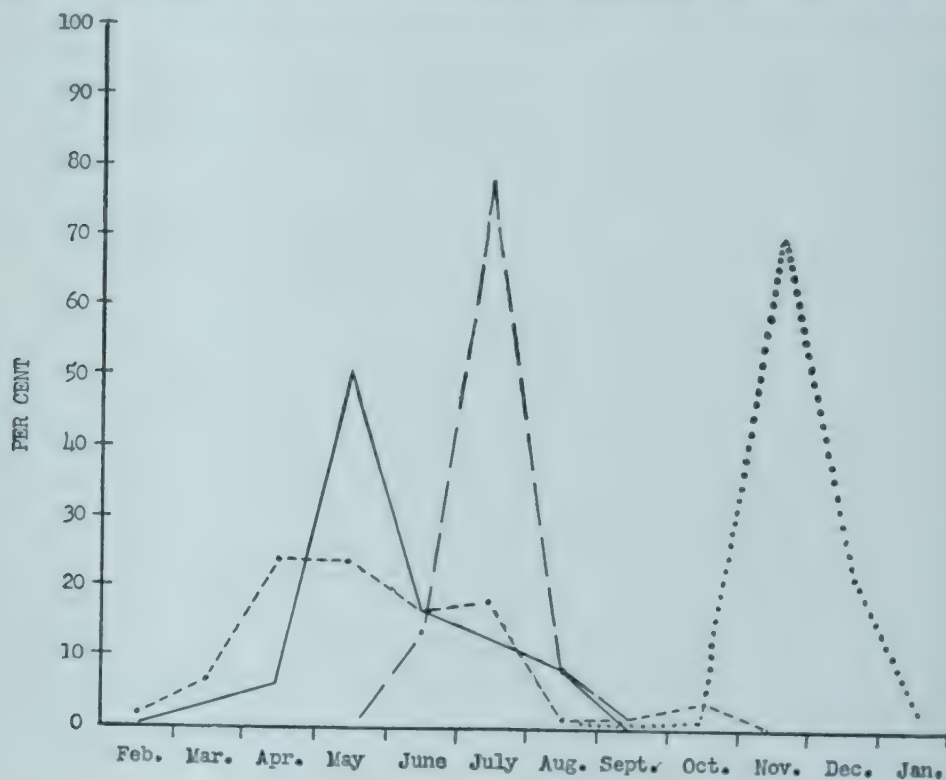
It is a function of epidemiology to distinguish between relationships which are fundamental to survival of a microparasitic population and those which are only incidental, i.e., to distinguish between transient hosts and reservoir hosts. By the latter term is implied the host relationships upon which the microparasite depends chiefly for its continuous propagation. While usually applied to vertebrate hosts, it would seem entirely appropriate to apply this term to arthropod vector hosts to which the microparasite has become adapted and in which it is able to survive for long periods of time with stage-to-stage transfer from one generation to the next, as with *Dermacentroxenus rickettsi*, the causative agent of Rocky Mountain spotted fever in ticks.

The epidemiology of these diseases may involve a considerable part of the ecology of a region. Indeed, as pointed out by Burnet (1951), the ecological point of view is fundamental to an understanding of the manifestations of such diseases. As the latter in human populations, the occurrence of cases of which is a reflection



of the waxing and waning of microparasitic populations in their extrahuman reservoir multiplication.

One epidemiological characteristic which these diseases have in common is that none is world wide in distribution. They are limited in their geography to localities or foci where the highly specialized conditions required for maintaining



Prepared from data in Pub. Health Rep., 52:107, 1937.

Fig. 43-3. Seasonal prevalence of tularemia.

Transmitted by: *D. andersoni* ———; *D. variabilis* - - -; *Chrysops discalis* — · —; rabbit contact ·····.

transmission can be realized. The second characteristic is that the immunity status of the human population is seldom an important limiting factor. Usually, the incidence in seasonal variation and in population group selection is determined principally by exposure to the arthropod vectors, to extrahuman hosts, or to both.

Many examples of progressive development of knowledge of diseases of this type have been given in previous chapters. A classical illustration is afforded by the account of "The Conquest of Yellow Fever" by Strode and others (1951). Briefly stated, the successive steps which led to the elucidation of the biological mechanisms involved in the maintenance of yellow fever virus in nature were the following: (1) clinical and pathological differentiation of the disease yellow fever beginning in the seventeenth century; (2) description of the epidemiological features of the disease, accumulated principally during the latter part of the nineteenth century (before routinely collected morbidity and mortality statistics were available), i.e., crude quantitative estimates of frequency and distribution in human populations, geographic location of endemic and epidemic centers, transportation and introduction into new areas by sailing ships, tendency when introduced to spread radially from the water front, disappearance from communities in the tem-

erate zone with the frost in the fall, formulation of the hypothesis of mosquito transmission by Carlos Finlay in 1881, observations on the period of extrinsic incubation by Dr. Henry Rose Carter in 1898; (3) the human experiments of the Walter Reed Commission (about 1900), proving that yellow fever could be transmitted by a mosquito, *Aedes aegypti*, and that the causative agent is an ultra-microscopic filtrable virus, thus establishing the man-*aegypti*-man propagation as the principal chain of transmission of urban yellow fever; (4) the development in the field of practical methods for suppressing *Aedes aegypti* populations in urban communities below the threshold at which transmission can be maintained, beginning in Havana, Cuba, in 1902; (5) discovery in the experimental laboratory of the susceptibility of the monkey in 1927 and, three years later, of the white mouse, leading to confirmation of experimental transmission by *Aedes aegypti* and other species, and to the development of the mouse protection test for the detection of specific antibodies in sera; (6) epidemiological field observations, in 1932, describing the occurrence of cases of yellow fever in areas where *Aedes aegypti* were not found and the selection of the disease for adult males engaged in wood cutting; (7) epidemiological organization of the viscerotome service (liver puncture) in Brazil about 1934, leading to the finding of cases of yellow fever in areas from which *Aedes aegypti* were absent and extension of the use of the mouse neutralization test to sera gathered from populations in various geographic areas in South America and Africa, outlining the distribution of the virus infection; (8) laboratory demonstration (1940-1946) of the presence of neutralizing antibodies and recovery of the virus from certain species of monkeys in South America and later in Africa, recovery of the virus from mosquitoes captured in nature in these areas (*Haemagogus spegazzinii* in Brazil and of *Aedes simpsoni* and *Aedes africanus* in Africa) elucidating the mechanism of propagation of the virus in a jungle; (9) laboratory development (1936-1943) of a simple practical method of vaccination; and (10) field trial (1937-1943) of the vaccine on human populations to assess its safety and the protection which it afforded the vaccinated as compared with the unvaccinated under conditions of natural exposure.

It will be noted that after the disease had been clinically differentiated, the development of knowledge which achieved the virtual eradication of *Aedes aegypti* transmitted yellow fever from the Western Hemisphere, and which yielded a practical means of prevention of human infections with jungle yellow fever in South America and Africa, was a stepwise process resulting from the alternation of epidemiological observation and chains of inference with laboratory experiments and field applications. At the same time, the synthesis of these chains of inference into a biological pattern, gave rise to an adequately supported concept of the manner in which the virus of yellow fever is continuously propagated in the human reservoir of primate and mosquito life in the jungle ecology, from which it occasionally emerges into human experience as sporadic cases or as epidemics, propagated, at least temporarily, by a vector (*Aedes aegypti*) which is adapted to the domestic economy of man.

**Noninfectious Diseases and Abnormal Physiological States.** Similarly, observations and reasoning based upon the manner of occurrence of noninfectious diseases and abnormal physiological states in human populations have been of value in contributing to the understanding of the underlying pathology. One of the classical



studies in history of epidemiology (although the author was unacquainted with this word) was "an inquiry concerning the cause of endemial colic in Devonshire" presented by Sir George Baker before the College of Physicians in London, June 28, 1767. He identified the clinical condition with which he was dealing as lead poisoning. He studied its distribution and selection in the population of Devonshire and the adjoining counties. The condition was largely confined to Devonshire, selected "people not very elegant and careful in their diet," occurred in the autumn, and was associated with drinking cider. Baker sought a rational explanation of why some of the people drinking cider were made sick and others were not. He found it in a difference in use of lead in construction of cider mills, the use of lead for storing juice and the use of sugar of lead as an adulterant to stop fermentation and to sweeten the cider.

In 1914, Dr. Joseph Goldberger was assigned by the U. S. Public Health Service to a study of pellagra, which at times had become quite prevalent in certain villages and institutions in South Carolina, Georgia and Mississippi. His approach to the problem was to observe the conditions under which the disease was occurring. In insane asylums, he noted that, although the disease was of frequent occurrence among patients, the doctors, nurses, attendants and orderlies in these same institutions were never attacked. He reasoned that, since the attendants had to handle, wrestle, and sometimes even fight with these patients, the disease could not be readily transmitted by contagion. He noted among other things that there was a significant difference in food consumed by pellagrinous patients and that consumed by the staff. In particular, members of the staff had nice cuts of meat and glasses of milk, whereas many of the patients were unable to feed themselves adequately with the limited dietary that was served to them.

Further in the course of his travels, Goldberger found two orphanages in southern Mississippi in which a considerable proportion of the children had symptoms resembling those of pellagra. On more careful analysis, he discovered the surprising fact that the disease was limited to children between the ages of 6 and 12; there was none among the younger nor among the older children. Again, by close observation, he discovered that two mugs of fresh milk were served each day to children up to six, the diet for children from 6 to 12 consisted of plenty of cornbread, hominy grits, biscuits, molasses, and there was on gala days once a week, fresh meat. The older children, 12 to 15 years of age, were allowed to assist in the kitchen and had opportunity to supplement their diet by milk and meat obtained surreptitiously. Goldberger drew the inference that this difference in diet explained the difference in age selection of the sick children. To test this hypothesis, the ordinary diet of all the children was supplemented by feeding fresh meat four times each week, two seven-ounce cups of milk each day and every child under 12 had at least one egg a day. Within a few months symptoms of pellagra had disappeared from the whole orphanage population.

These observations led to the formulation of an hypothesis that pellagra is due to a deficiency of fresh meat, milk, eggs and other protein foods. This hypothesis was tested and confirmed by human experiment carried on at a Mississippi state prison. It was consistent with the findings of an extensive study in several cotton mill villages in South Carolina, correlating the prevalence of pellagra and its selective occurrence with economic, dietary, seasonal and other factors and

conditions. Finally, the hypothesis was put to experimental test in dogs, who were known to suffer from an analog of pellagra, known as "black tongue." This led to the subsequent work of many investigators which elucidated step by step the role of B vitamin complex in nutrition.

Other examples could be cited, but these will suffice to illustrate the manner in which the epidemiological method can be applied to the problems presented by diseases of unknown etiology, to deficiency states, to industrial hazards, to disturbances of growth and metabolism, etc. The essence of the method is to compare the frequency of occurrence of the disease or state in various groupings of persons in relation to time, place, and factors and conditions which appear to be, or may be, of causal significance according to the hypothesis which guides the investigation.

The study of the epidemiology of some thing or event—cancer, for example— involves a recognition of the event we are talking about, so that the population can be separated into those who have cancer and those who have not. Moreover, the study demands classification of the population on other axes to determine the important related factors that single out these particular people for attack. Are they different in inheritance, in nutrition, in occupation, and so forth, from the rest of the population?

Considerable imagination is required in seeking out the pertinent variables to study. We may search along one axis of classification assiduously and neglect some other more relevant one, and thus the real relationship may elude us. The study of cholera in London might be recalled, in which Farr showed that there was a diminishing proportion of people attacked as the altitude increased. This fitted beautifully with the miasma theory of disease. It happened also that the water supply got increasingly better with altitude, and that water was the relevant axis of classification, altitude being merely incidental. If we are able to separate our population with regard to an event whose epidemiology we are studying and if we are able to relate this classification to the factors which produce it, we will understand the epidemiology of an event.

**Biostatistical Approach.** Up to this time little has been said about the employment of biostatistical methods and technics in epidemiology. In many such investigations the requirements for quantitative statement and comparisons may be relatively simple, a matter of numbers, simple rates and ratios, to which reference has been previously made. Other investigations require the employment of extensive statistical data based upon reports of cases or deaths, sometimes systematically collected over long periods of time, related to the population composition of community or region, or are concerned with the evaluation of the effectiveness of measures of prevention, prophylaxis, or control requiring experimental design. While the validity of epidemiological inferences drawn from such studies depends primarily upon the accuracy of the original observations and biological concepts, it is affected to an equal degree by the soundness of the statistical methodology used.

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## STATISTICAL REASONING

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**Introduction.** "The black plague that ravaged Europe is all but gone. The yellow fever that made men pray for winter is all but gone. The malignant choking path that struck at children is all but gone. Purging fevers no longer haunt the water that cities drink. Cheeks that would once have been pitted with smallpox are smooth and fresh. Men and women die old.

"Are we then so wise that we have beaten our parasites? Sallow-faced farmers shivering and burning with malaria, bedside watchers listening to the anxious wheezing of pneumonia, jaded nurses tending the wrecks of syphilis, millions exasperated by the nagging misery of the common cold know the answer. We have not tamed the world entirely of any single infection known to man, and some we have not yet begun to fight. As for the premises for action, we do not yet know why one man sickens and the next goes free, why one pest seeks out the lungs and another the liver, how drugs cure the ills they seem to cure, how disease begins or how it ends" (Smith, 1948).

Thus Geddes Smith, concerned perhaps lest we rest on past laurels, reminds us that there is yet much to be done. One learns from past experience, however, as Smith himself demonstrates in the body of his book, and the lesson to be learned here is that such understanding as we have gained of health and disease has been through the patient study of many workers of the relationship between man and his environment, biological, physical, and social. The study of this relationship is essentially the study of variation and the exploration of this variation constitutes the avenue along which we may hope to find the "premises for action" which will tell us why "one man sickens and the next goes free." Because the statistical method is one of the most powerful tools available for the study of variation, this chapter is concerned with the nature of the reasoning process underlying the application of this method to the study of man and his responses to his total environment.

**Formulation of the Problem.** The first step toward answering such questions as why one person gets sick and another doesn't, whether penicillin is effective in the treatment of certain types of cardiovascular syphilis, why certain diseases such as rheumatic fever show a high familial concentration, and so on, is a careful statement of the question itself. The more sharply it is possible to focus the hypothesis to be tested, the more likely it is that an unequivocal answer will be forthcoming.

Suppose, for example, it is desirable to evaluate the effectiveness of a particular therapeutic or prophylactic procedure—operation, drug, x-ray, bed rest, immuni-



zation, etc. The question in its initial form might be as follows: Does the procedure cure the disease? Expressed in this way it is very difficult to judge the value of the procedure, for there may be any number of different interpretations of what is meant by "cure." However, the question may be restated in more specific terms. If by cure is meant to reduce the chances of dying within a specified period of time, then the question may be put somewhat as follows: Does the procedure reduce the mortality from this disease and how does this reduction vary with the time since the procedure was instituted? Still another interpretation of cure might be in terms of the frequency with which recurrences of certain manifestations occur after treatment. The question would then be worded accordingly. The more specifically the therapeutic objective is defined, the simpler it is to determine whether this objective is attained and to what extent such attainment is due to the particular therapy employed.

Analogous problems are equally frequent in the public health field. Consider the well-baby clinic. Does it do any good? It is not possible to answer the question in this form because it does not pose a hypothesis to be tested. However, if one hypothesizes that children who come to well-baby clinics have a lesser frequency of childhood diseases than those who do not attend, this contains the possibility of being tested if the necessary data can be obtained. A number of other hypotheses in relation to the activities of a well-baby clinic, such as those concerned with measures of growth, will suggest themselves.

The reader is referred to a paper by Whelpton and Kiser (1945) for an excellent example of the principle of developing specific hypotheses to be tested before undertaking collection of data.

**Planning the Collection of the Data.** The kind of data to be collected and the manner in which the collection is made are dependent upon the hypotheses to be tested or the way in which the basic questions are phrased. Suppose, for example, one wished to test the hypothesis that whooping cough immunization reduces the occurrence of the disease. This requires that information concerning the occurrence of the disease during a stated period of time be obtained from every child who received the vaccine. Some decision would have to be made as to what is to be counted as a case of whooping cough. Will history be sufficient? Will cough plates be required? The more objective the definition, within the practical limitations of the situation, the better. A decision must also be reached as to how the information is to be obtained. Is it to be by getting the history from the mother at the end of a period such as a year or is it to be by periodic visits at fairly frequent intervals so that the memory factor is reduced to a minimum?

A very important requirement dictated by the nature of the hypothesis is that information similar to that obtained on the inoculated group must also be obtained on a group of noninoculated individuals. Otherwise, it would not be possible to determine whether the frequency of attack among the inoculated group was reduced by the inoculation. In other words, a control is essential. Topley (1940), illustrating the point, speaks of Broussais, a French clinician of the early nineteenth century who believed that the way to treat infectious disease was to bleed the patient. Under his aegis, the consumption of leeches in France rose sharply until Pierre Louis decided to see what happened to the patients who had not been leeches. As Topley puts it, "the results lent no support to the leeches."

The purpose of a control is to permit the isolation of the factor responsible for the observed result in the study or experimental group. It is essential, therefore, that the control group be similar to the study group in every respect except the one which is the object of study. This is not an easy requirement to fulfill. In laboratory experiments, the investigator usually begins with a group of animals which he then divides into two subgroups, one of which is experimented upon, the other remaining as the control. The division into two subgroups is usually accomplished by some kind of randomizing process which will insure that the groups do meet the above requirement. In studies on man similar to that on the efficacy of whooping cough immunization, attempts to set up controls through a randomizing process often meet with difficulty, because if there is some chance that the treatment immunizing agent will be effective, it is hard for the physician to deny it to some individuals. However, "it is easy to fall into the error of assuming that a new drug (or other agent) must be good and, therefore, it is unethical to withhold it from a patient . . . It may well be that those from whom the drug (or other agent) is withheld are in fact the fortunate ones, and that by not setting up a control this fact is not immediately discovered" (Merrell, 1949). Excellent examples of well planned studies of therapeutic or prophylactic agents are reported by Merrell (1949), the Medical Research Council (1948), and Kendrick and Eldering (1939).

In studies concerning therapeutic or prophylactic agents of one sort or another, whether they be conducted in the laboratory or among population groups, the researcher usually makes the decision as to who shall receive the agent and who shall not. There is a whole class of studies, however, in which the separation into two groups to be compared has taken place prior to the time the material comes to the attention of the investigator. However, the problem of determining whether the study and control groups are alike in every respect except that under consideration still remains. For example, one may ask the question whether household contacts to cases of tuberculosis have a greater or lesser mortality than the population in general (Frost, 1933; Brailey, 1940; Puffer, 1946). Here the investigator is not in a position to decide which individuals shall be among the group, "household contacts of tuberculosis." He must accept the data as they come to him. It becomes his responsibility, however, to compare the study group (contacts) and the control group (population in general) with respect to characteristics other than mortality such as age, sex and race to see if they are the same, or, if they differ, to ascertain the effect of the difference on mortality. The reader will readily think of other situations in which this problem arises. Berkson (1946) discusses the issue with respect to the conclusions which may be drawn from certain kinds of hospital data and Puffer (1950) the general issue of designing studies as exemplified by certain psychological studies made during World War II.

Whenever the basic question or objective of a study is of the form: What is the relationship between A and B?, a control is a *sine qua non* of the study. For example, if, as in the previous paragraph, we raised the question of the relationship between contact with tuberculosis and mortality, a control will be necessary. There are many studies, however, in which a control is not required. In these studies, the basic question is of the form: How much is there of A? For example, what is the prevalence of cancer in the population, or any other question of this form.

Although a control is not a requirement of studies concerned with the second



type of question mentioned above, there are other points to be considered, chief among which is the representativeness of the material. For example, suppose one wishes to determine how much syphilis is present in the population of a city at a particular time. There are several ways of deciding what shall be counted as syphilis (Turner, 1943) but for the present purpose we shall be concerned with the frequency of infection as evidenced by a positive serological test. If it were possible to obtain a serological test on every person in the city, the prevalence of syphilitic infection could be established.\* Ordinarily, of course, this is not practicable and a sample of the population is obtained instead. It then becomes necessary to consider how representative the sample is of the entire population. If the city has a high proportion of nonwhite population, the sample should contain essentially the same proportion of nonwhites. If the sample proportion is too high, the estimate, based on the sample as a whole, of the proportion of the population having a syphilitic infection will be too high, because, in general, syphilis is more widespread among the nonwhite population (see page 1316). In general, the sample must have essentially the same composition as the population from which it is drawn if reliable inferences are to be made about that population. Tabulation of the data from the sample should examine this point.

The technical problems of developing the specific forms used in a study, of insuring uniformity in filling them out, of deciding the exact method of obtaining a sample, of training enumerators to gather data if a field survey is involved are beyond the scope of this chapter. It is suggested that the reader examine a number of the references at the end of this chapter and the next with respect to these points. Puffer (1950) and Pearl (1940) discuss some of these points.

The discussion to this point has been concerned with the *planning* of studies—with the reasoning process involved in deciding what data shall be collected, and from whom it shall be collected. Unless the study is carefully planned in relation to the initial question or hypothesis to be tested, no amount of statistical manipulation of the data after they have been collected will provide clear-cut answers. It follows from this that the planning of studies is primarily a matter of teamwork between the investigator (and his staff) and the statistician. This teamwork must begin at the beginning—at the formulation of the problem and in the planning of all subsequent stages. Otherwise, the benefit to be derived from such teamwork is likely to be no greater than that derived by the patient if the clinician seeks consultation after the patient is dead.

**Tabulation of Data.** Tabulation is merely a systematic arrangement of the data which have been collected. Such an arrangement is absolutely essential if one is to obtain a picture of the interrelationships among items. Suppose, for example, in connection with the operations of a tumor clinic, a question is raised as to how the interval of time between onset of symptoms varies with the sex of the patient and the status of the tumor at the time of the patient's first visit to the clinic. The answer to such a question could be of considerable value in planning an educational program concerning the desirability of early medical consultation if there are suspected symptoms.

The basic data for answering the question would be in the records of patients

\* Within the limitations of the serological test itself.

tending the clinic. A simple listing of the pertinent facts with regard to each patient would provide data such as the following:

Patient	Sex	Status of Tumor	Interval between Onset of Symptoms and Consultation
A.W.	F	Primary	4 months
T.G.	F	Primary with regional metastases	8 weeks
P.F.	M	Remote metastases	1 year
		etc.	

Clearly some sort of organization of such a listing would be required if the association between sex, status of tumor, and the time between onset of symptoms and seeking consultation is to be studied.

Whatever organization is attempted, it must be able to answer this type of detailed question: How many females with a primary tumor without metastases were seen within one month, two months, etc., of the time of recognition of symptoms? How does this compare with the females in whom the tumor was found to be primary with metastases? To answer questions of interrelationships such as these, the data must be cross classified, with the items placed in relation to each other as follows:

Time Between Recognizing Symptoms and Consultation	Status of Neoplasm on Admission						Total by Sex		Grand Total
	Primary		Primary with Metastases		Secondary				
	M	F	M	F	M	F	M	F	
ss than 6 months									
months to 1 year									
year to 1 year and									
6 months									
etc.									
TOTAL									

This kind of table will answer all questions regarding the three factors: time interval, status of tumor, and sex, and their relationships to each other.

From this discussion, certain general principles of tabulation emerge, the most important of which is that the form of tabulation which is used is dependent upon the specific questions to which it is desired to obtain answers. It is a very useful procedure in the planning of studies to attempt to sketch out table formats. This will help to insure that all the information needed to give the desired answers is obtained, and will often sharpen up the questions which are under investigation. Setting up dummy table forms also makes it possible to get a rough idea of how many observations are needed to make the table worth while. For example, it is readily seen that if, in addition to the three items in the above table, we wish to add the kind of tumor, a great many more observations would be necessary than without that added breakdown.

The attempt to classify or systematically arrange the data in a table in itself means that decisions must be made as to what classifications to use. For instance, in the previous example, some decision would have to be reached as to what time



intervals are to be used. Should it be individual months, years, or six-month periods as in the above table? How should the status of the tumor be classified? Should metastases be further broken down into those which are regional to the primary tumor and those which are remote? What is meant by "secondary"? These are questions which must be decided before the data are tabulated. The actual decision must be made by those familiar with the material, and must be suited to the purpose at hand.

The process of classification reveals that there are in general two kinds of data. These can be distinguished by the characteristics of the scale along which they are classified. Whenever the division points on the scale can be identified numerically, the data are referred to as *measurement data*, and the table showing the frequency with which observations occur along the scale is known as a *frequency distribution*. Data on age, weight, blood pressure, temperature, etc., are measurement data. Table 44-5, page 1330, shows a frequency distribution of weight at birth of first-born infants.

The classification of data when the scale of classification cannot be marked numerically is much more difficult. Consider, for example, the classification of cases of tuberculosis as to stage of the disease at time of discovery—minimal, moderate, far advanced. Where is the dividing line between minimal and moderate? The classification, here, is based on some attribute of the material rather than a measurable characteristic, hence these are known as *attribute data*. Examples are data classified by stage of disease (as in tuberculosis), diagnosis, sex, race, etc.

The importance of making the distinction between these two types of data lies in the fact that because of the relative objectivity of measurement data, most investigators will agree on a definition of where the division points on the scale fall so that observations classified in this manner have the same meaning for almost everyone. This is not the case, however, with attribute data. Even a superficial examination of the tuberculosis literature, for example, indicates quite a bit of disagreement as to what is a minimal, moderate, or far advanced case, or even as to what is a case (Birkelo, 1947). The point, however, is that some definition must be agreed upon before it is possible to make meaningful tabulations (Densen, 1949).

Since the objective of tabulation is an orderly presentation of the observations, it is important that a table be so organized as not to require reference to the text to be understood. Table titles should be explicit as to the kind of data presented in the table, what time period they cover and for what area they have been collected. Heads of columns and rows should be clearly marked and the units in which the data are expressed clearly shown. Whenever percentage or rates are presented, the base on which they are computed should be indicated. The reader is referred to Walker and Durost (1936) for more detailed discussion, and to Puffer (1950) and Pearl (1940) for procedures in the mechanical handling of various types of records.

**Graphical Presentation of Data.** The presentation of statistical material in graphic form is a device for emphasizing salient points which may be lost in the mass of figures in a table. There are many varieties of graphs, a few of which are illustrated in this and the next chapter. Ordinarily, the graph of attribute data takes the form of a *bar graph* such as is shown in Figure 45-10 (page 1369). When one wishes to show the trend of data with time, a *line diagram* (Fig. 45-6, page 1356) is used. At times, however, one may be interested in the relative or percentage

ange with time as well as the amount of change, in which case a ratio or *arithmic line diagram* may be used (Fig. 45-12, page 1373). When dealing with measurement data, a *histogram* (Fig. 44-4, page 1331) is often used to show the general characteristics of the frequency distribution.

The points to be considered in construction of graphs such as those just mentioned may be found in Pearl (1940) as well as in many other standard statistical texts. The reader is also referred to Weld (1947) for an extensive treatment of the subject. One general point may be made here, however. The test of a good graph whether it is readily understandable without recourse to the table containing the data from which the graph is drawn. Rules for achieving this desideratum are presented in the references just cited.

**Analysis.** The process of analysis is essentially one of comparison—comparison, for example, of the mortality (or some other measure) of those treated with a drug and those not treated, or of the subsequent experience with the disease of those inoculated against whooping cough and those not inoculated, or of the mortality of household contacts of cases of tuberculosis compared with that of the rest of the population, etc. When such comparisons are made, it is the exception rather than the rule to find that the absolute numbers in the two groups being compared are exactly the same. It may happen then that there are more deaths, for example, in the treated group than in the untreated group, simply because there are more people in the former exposed to the risk of dying during the period of observation. It therefore becomes necessary to take account of the numbers in each group. The simplest way to do this is to relate the deaths during a period of time, if that is the event in which interest lies, to the population exposed to risk during this time. The resulting figure is a death rate.

In the study of the interplay of the various factors concerned in the production and control of disease, a great many different kinds of rates are used. Each serves a different purpose and is subject to a different interpretation, but all are based on certain fundamental principles. These are most easily arrived at by considering the construction of certain rates as examples. The crude death rate serves as a good starting point. This rate is found according to the following formula:

$$\text{Crude death rate} = \frac{\text{total deaths during a given period of time}}{\text{average population present during period}} \times 1,000$$

This is a very simple rate to compute. The numerator is obtained by adding up all the deaths that occurred during the period of time for which the rate is being computed (usually, but not necessarily, a year). The denominator is the average population present during the time period.\* If a count of the average population is not available, some estimate of it must be made.\* The following example gives the computation of the crude death rate for Pittsburgh in 1949:

$$\frac{\text{total deaths in 1949}}{\text{estimated average population, 1949}} \times 1,000 = \frac{8,507}{714,874} \times 1,000 = 11.9$$

\* The usual procedure for collecting the information on deaths and for estimating the population is considered further in the chapter on Health of the Population.



This figure may be interpreted as meaning that, on the average, for every thousand individuals in the population of Pittsburgh in 1949 there were nearly 12 deaths.

**Factors Influencing Crude Rates** (see page 1358). The crude death rate is a composite of the death rates of the various classes of the population. If, for example, the proportion of colored people in the population is high, the crude rate will be pulled toward the death rate of the colored people and it, too, will be high (see page 1312). This important point may be illustrated by the following hypothetical example:

Age Group	City A			City B		
	Population	Deaths	Death Rate per 1,000 Population	Population	Deaths	Death Rate per 1,000 Population
Young	1,000	10	10.0	2,000	20	10.0
Old	2,000	40	20.0	1,000	20	20.0
Total	3,000	50	16.6	3,000	40	13.3

It would appear from an examination of the crude or total death rates that mortality conditions in City A, with a crude rate of 16.6 per 1,000, are somewhat worse than in City B, where the rate is only 13.3 per 1,000. But on closer examination it is seen that the death rate in each of the two classes of the population—*young and old*—is exactly the same. The sole reason for the difference in the crude rates lies in the *differing proportions of young and old population* in the two cities. City A has a higher proportion of its population in the group with the high death rate—i.e., in the old group. This group exerts a stronger pull on the total death rate in City A than in City B; hence, the crude rate is higher in the former than in the latter.

Table 44-1. Age distribution of cases and deaths among males and case fatality ratio of Rocky Mountain Spotted Fever occurring in certain western\* and eastern\* states

Age in Years	West			East		
	Cases	Deaths	Deaths per 100 Cases	Cases	Deaths	Deaths per 100 Cases
0-14	55	5	9.0	170	23	13.5
15-39	239	32	13.3	124	17	13.7
40 and over	330	145	43.9	107	43	40.1
All ages	624	182	29.1	401	83	20.6

From Topping, N., Pub. Health Rep., 56 1699, 1941.

\* The western states are Montana and Idaho, while the eastern states are Maryland and Virginia. All cases and deaths are reported to the State Health Officer; Montana, Idaho, and Maryland, 1930-39, inclusive; Virginia, 1933-39, inclusive.

The data in Table 44-1 (Topping, 1944) illustrate the importance of this point in relation to the study of factors influencing the occurrence of disease in a population group.

"In spite of several published statements to the contrary, it has long been the popular conception that Rocky Mountain spotted fever is a more highly virulent, and, therefore, a more fatal disease in the West than in the East" (Topping, 1941). The large difference between the two areas in the crude case fatality ratio for males of all ages would seem to bear this out. However, examination of the rates for individual age groups shows that in the two younger groups the ratio is actually slightly greater in the East than in the West, and in the oldest group the difference is considerably less than that for all ages. It will be noticed, however, that there is an entirely different age distribution of cases in the West than in the East, the former having a much higher proportion of cases in the older ages. The result is to pull the total ratio for all ages in the West up toward that of the 40 and over group. The disparity in the ratio for all ages \* is, therefore, largely due to the differences in age distribution in the two areas. Similar data are presented in the paper for females. The author concludes that there is no support in the data presented for the "popular conception" quoted above.

These examples illustrate two major considerations with respect to rates. These are: (1) rates are only comparable if the populations upon which they are based are comparable, and (2) that comparisons are best made in terms of rates for specific groups of the population. Such rates are known as *specific rates*. Rates are frequently made specific for race, sex, and age, or for any combination of these. The principle of constructing specific rates, however, need not be confined to these three factors. Rates may be constructed for any factor being studied, *as long as the numerator can be related to the population from which it arises*.

The principle of relating the numerator to the proper denominator is well illustrated by tracing the formation of the *maternal mortality rate*. The maternal mortality rate is a measure of the risk to the mother of dying from causes associated with childbirth. The numerator of the rate is the total number of deaths due to puerperal causes † occurring during the time period in which we are interested—say, one year. The denominator should be all those individuals exposed during the year to risk of appearing in the numerator. This is certainly not the total population, since males do not experience this risk. Neither is it the total female population, for only those females in the reproductive ages—say 15 to 50—are subject to this risk. However, in any given time period such as one year, the only females in the reproductive ages who are actually exposed to this risk are those who become pregnant. The denominator, then, should be the total number of females who become pregnant during the year.‡ This, of course, is not a figure which is readily obtainable. However, a good approximation to it can be obtained by substituting

\* It is possible to adjust the total ratio for the difference in age distribution. The procedure for doing this, known as the adjusted or standardized rate procedure, may be found in most statistical texts dealing with medical or public health statistics.

† The decision as to what constitutes a "puerperal" cause is usually made according to the International List of Diseases, Injuries, and Causes of Death.

‡ Since some of the deaths may occur in the following year, a small error is introduced which, however, is ordinarily compensated for by death of mothers becoming pregnant in the previous year.



the number of live births for the number of females pregnant during the year, since for every live birth there must be a mother exposed to the risk of dying from the hazards associated with childbirth. (A small correction is ordinarily made for plural births.)

Thus, the maternal mortality rate as ordinarily computed is given by:

$$\frac{\text{deaths due to maternal causes}}{\text{live births}} \times 1,000$$

The objection might be raised that mothers whose pregnancies terminate in a stillbirth are just as much, if not more, at risk of dying from maternal causes as those whose babies are born alive, and, therefore, the denominator should be total births (live births plus stillbirths) rather than just live births. Logically, this argument is correct, but because of the unreliability of stillbirth data these are not included in the denominator of the rate.

**Rates and Ratios in Common Use and Their Formulae.** The following rates and ratios are frequently encountered:

1. Crude birth rate

$$\frac{\text{number of births during a calendar period}}{\text{average population present during same period}} \times 1,000$$

2. Crude death rate

$$\frac{\text{number of deaths during a calendar period}}{\text{average population present during same period}} \times 1,000$$

3. Age-specific death rate

$$\frac{\text{number of deaths in a particular age group (e.g., 25-34) in a calendar period}}{\text{average population in same age group during same calendar period}} \times 1,000$$

4. Infant mortality rate

$$\frac{\text{number of deaths under 1 year of age in a calendar period}}{\text{number of live births during same calendar period}^*} \times 1,000$$

5. Neonatal mortality rate

$$\frac{\text{number of deaths under 1 month of age in a calendar period}}{\text{number of live births during same calendar period}^*} \times 1,000$$

6. Maternal mortality rate

$$\frac{\text{number of deaths from puerperal causes during a calendar period}}{\text{number of live births during the same calendar period}} \times 1,000$$

7. Cause-specific death rate

$$\frac{\text{number of deaths from a particular cause during a calendar period}}{\text{average population present during the same calendar period}} \times 100,000$$

8. Case rate or morbidity rate

$$\frac{\text{number of cases of a particular disease developing during a calendar period}}{\text{average population present during the same calendar period}} \times 1,000$$

\* The number of live births is used because of difficulty in counting the population under one year or one month of age.

## 9. Case fatality ratio

$$\frac{\text{number of deaths from a particular cause}}{\text{number of cases of the same cause}} \times 100$$

## 10. Prevalence ratio

$$\frac{\text{number of cases of a particular disease at a particular time}}{\text{population present at that time}} \times 100$$

The multiplying factors shown in the above formulae are those which are most frequently in use; other multiplying factors may be used if desired as long as they are always stated in the presentation of the material. The calendar period ordinarily used in calculating rates 1 through 8 is one year, although at times it may be computed for longer or shorter periods. It will be noted that formulae 9 and 10 are designated as ratios and that they do not refer to a *period* of time. This brings us to consideration of two fundamental types of rates used in the study of biological phenomena—incidence rates and prevalence rates.

**Incidence and Prevalence.** The increasing importance of the chronic diseases has led to the recognition that there are two fundamentally different measures of the frequency of disease in a population, regardless of the type of population. One of these measures the rate of occurrence of the phenomenon *during* a given period of time. This is an *incidence rate*. The other measures the proportion of the population which exhibits the phenomenon *at* a particular time. This is a *prevalence ratio*.

The general formula for the prevalence ratio is given above. For the incidence rate, the general formula may be written as follows:

$$\text{Incidence rate} = \frac{\text{number of events in the population at risk during the specified time}}{\text{mean population at risk of event during specified time}}$$

Comparison of the general formula for the incidence rate with rates 1 to 8 above will show that they are all incidence rates. The event used in the formula may be death, the occurrence of a case, the occurrence of certain symptoms or any defined phenomenon.

The general relationship of prevalence and incidence may be expressed as  $P = I \times D$ , where  $D$  is the average duration of the disease in an individual case expressed in the same time units as  $I$ . From this formula, it may be seen that when  $D$  is short, as in the case of the acute infectious diseases, the prevalence is usually not very different from the incidence of disease. However, in the case of diseases such as tuberculosis, syphilis, cancer, etc., the prevalence may be very much greater than the incidence. Puffer (1950) shows how these relationships may be used to explain why, although the Negro death rate from tuberculosis is much higher than the corresponding white death rate in Tennessee, the prevalence figures are less in the former group than in the latter. The studies of Turner (1943) on the principles concerned in measuring the frequency of syphilis also revolve around this basic distinction between incidence and prevalence.

**The Life Table Approach to the Determination of Incidence Rates.** The determination of an incidence rate requires keeping a group under observation over a period of time, recording the event of interest when it occurs. If everybody entered a study at the same time and nobody was added or dropped out during the study



except by reason of experiencing the event, it would be fairly easy to determine the numerator and denominator of the incidence rate. However, the usual situation is that a certain number of individuals are available for observation at the beginning of the study, others are added later, some drop out because they experience the event under study, others drop out for other reasons. Thus, a listing of the experience of individuals in a study might be as follows:

Individual No.	Date of Entry to Experience	Date Leaving Experience	Reason for Leaving Experience	Length of time in Experience
1	January 1	December 31	end of study	365 days
2	July 1	December 31	end of study	184 days
3	Sept. 15	December 31	end of study	107 days
4	May 10	October 1	death	194 days
5	January 1	July 1	withdrew	181 days
6	January 1	August 15	lost to observation	227 days
7	August 15	December 31	end of study	138 days
8	February 20	Sept. 1	death	192 days
9	October 10	December 31	end of study	82 days
10	January 1	May 1	withdrew	120 days

Total experience 1,790 days = 4.9 yrs.

The problem of computing the incidence rate from such material lies in the determination of the denominator of the rate; i.e., the mean population at risk of event during the specified time. This is accomplished by making use of the concept of a *person-time unit of observation*. The time unit is usually a year, but it may be any other unit. A person in the experience for a full year (if that is the unit used) is said to contribute a person-year of experience to the observations. Two people in the experience for half a year will each contribute half a person-year experience. Together they contribute one person-year of experience. Thus, the 10 people in the above listing have contributed a total experience of 4.9 person-years or the arithmetically equivalent experience of 4.9 persons present in the study for a full year. Since there were two deaths in this experience, the average annual death rate is, substituting in the general formula for the incidence rate:

$$\frac{2}{4.9} \times 1,000 = 408.2 \text{ per thousand}$$

It will be noted that this device permits individuals who experience the event (individuals 4 and 8 in the above example) or who leave the experience for other reasons before completion of the study (individuals 5, 6, and 10) to make their contribution to the total up to the time they leave the experience. It is, perhaps, easier to see that the time factor must be taken into account by rewriting the general formula as follows:

$$\text{Incidence rate} = \frac{\text{number of events in population at risk during observation}}{\text{person-time units of risk during observation}}$$

Table 44-2. Experience of children in test and control groups in study of active immunization against pertussis

Time Period in Months	Number of Children						Person-Months at Risk $L_x = l_x + \frac{(n_x - d_x - w_x)}{2}$	
	Present at Beginning of Month $l_x$		Number Entering Study During Month $n_x$		Number Withdrawing During Month for Specified Reason			
					All Other Reasons $w_x$			
	Pertussis Attack $d_x$		Test		Control			
	Test	Control	Test	Control	Test	Control	Test	Control
1	1,403	1,605	79	66	4	19	30	38
2	1,448	1,614	45	26	2	21	11	41
3	1,480	1,578	60	19	3	24	8	21
4	1,529	1,552	5	18	2	33	19	37
5	1,513	1,500	10	14	7	35	25	40
6	1,491	1,439	18	17	8	33	29	57
7	1,472	1,366	13	12	3	20	73	83
8	1,409	1,275	12	17	5	40	74	73
9	1,342	1,197	9	6	2	14	467	404
10	882	767	3	3	1	4	819	691
11	65	75					57	74
Total					37	243		13,336.5
							Total person-years	1,111.4
								1,095.7

$$\text{Annual incidence or attack rate} = \frac{\text{Number of attacks}}{\text{Person-years of risk}} \times 100$$

$$\text{Test group} = \frac{37}{1,111.4} \times 100 = 3.3\%$$

$$m_x = \frac{d_x}{L_x}$$

$$\text{Control group} = \frac{243}{1,095.7} \times 100 = 22.2\%$$

Adapted from Tables 2 and 4, "A Study in Active Immunization Against Pertussis," by Pearl Kendrick, Am. J. Hyg., Vol. 29, No. 3, Sec. B., May, 1939.



In a practical problem involving larger numbers of observations than the above example, it is ordinarily easier to tabulate the entry and exit of an individual in a time period rather than to record the exact date of entry and exit, although this information should be available for each individual. The procedure for arriving at the person-time units of exposure is then carried out by a modified life table procedure as illustrated by the material in Table 44-2 adapted from a paper by Kendrick and Eldering (1939) concerned with the efficacy of immunization against pertussis.

Referring to the first line, the table shows that 1,403 individuals entered the test group in the first time period. If these 1,403 remained in the study throughout this time period of one month, they would contribute 1,403 person-months of experience. But during this first month, 79 individuals entered the test group. Since the exact date of entry is not being recorded, some may have entered in the early and some in the latter part of the month. On the average, it may be considered that each of the 79 individuals contributes one-half a month to the experience. Up to this point, therefore, we have accumulated  $1,403 + \frac{79}{2} = 1,442.5$  person-months of experience. However, some of these individuals were withdrawn from the test group during the month—four because they developed pertussis and 30 for other reasons. These individuals have already been counted in the experience, but since, on the average, they are in the experience only half a month, the other half should be subtracted from the experience. We then have as the accumulated person-months of experience

$$1,403 + \frac{79}{2} - \frac{4}{2} - \frac{30}{2} = 1,403 + \frac{79 - 4 - 30}{2}$$

$= 1,425.5$  person-months of experience as shown in the table.

Since during the first month we started with 1,403 individuals and added 79 more while 34 left the experience, we have  $1,403 + 79 - 34 = 1,448$  individuals present in the test group at the beginning of the second month. The procedure for calculating the person-months of exposure during this second time period is then repeated.

We may summarize the computational procedure as follows, the symbols under the wording being the conventional life table symbols:

$$\begin{array}{l} \text{Person-time} \\ \text{units of} \\ \text{exposure} \end{array} = \begin{array}{l} \text{number present} \\ \text{at beginning} \\ \text{of interval} \end{array} + \frac{1}{2} \left( \begin{array}{l} \text{number} \\ \text{entering} \\ \text{during} \\ \text{interval} \end{array} - \begin{array}{l} \text{number ex-} \\ \text{periencing} \\ \text{event during} \\ \text{interval} \end{array} - \begin{array}{l} \text{number withdrawn} \\ \text{during interval} \\ \text{for other reasons} \\ \text{than events} \end{array} \right)$$

$$L_x = l_x + \frac{1}{2} (n_x - d_x - w_x)$$

Having the person-time units of exposure (in this case, months) it is now possible to compute the incidence rate for the event—in this case, an attack of pertussis. The formula, with accompanying symbols, is:

$$\text{Incidence rate} = \frac{\text{number of events in population at risk during observation}}{\text{person-time units of risk of exposure}}$$

$$m_x = \frac{d_x}{L_x}$$

The table shows this same procedure carried through for each month of the study for both test and control groups. The total person-months at risk for each group are shown at the bottom of the table. These are converted to person-years by dividing by 12 and the annual attack rates are computed according to the formula.

Typical instances in which the foregoing process is employed are evaluation of the effectiveness of therapy following completion of treatment, the determination of the effectiveness of prophylactic procedures as in the example just given, the estimation of the chance of developing a particular disease or condition within a given period of time after observation, etc. Any dynamic process may be analyzed in this fashion. The basic information needed is the date of entry to the experience, the date of exit from the experience, and knowledge of the event when it occurs. Usually the material is tabulated in whatever time intervals are appropriate to the phenomenon under consideration—a year, a six-month period, a month, etc. One of the earliest examples of the use of this procedure may be found in Frost (1933). Berkson and Gage (1950) illustrate its use in the calculation of survival rates for cancer.

When the event to be recorded is death, there is usually no difficulty in determining in which time period it occurred. When, however, the event is some phenomenon such as change in immunological status, this is not always so easy. For instance, the event to be recorded may be change from a serological positive state to a negative one. Now suppose individual A is observed as being positive in the first three time periods (a time period might be six months) but he is not seen in the fourth time period, and when he is examined in the fifth time period he is found negative. The question arises as to how his serological state should be recorded in the fourth period. The reader is referred to Harris and others (1949) for a discussion of this problem. Where possible, of course, it is best that there be no gaps in the observations.

## THE GENERALIZATION OF OBSERVATIONS

It is rare that any given study is undertaken for the sake of the observations themselves. Rather, the objective is to obtain a set of facts which may serve as the basis for predictions about similar situations, that is, the observed material is expected to serve as the basis for generalization.

In the problem on immunization against pertussis, the value of the study lies in what these observations tell us about the effect of immunization on the attack rate of pertussis in general—that is, at any time immunization is given—not in the fact that, in this particular instance, there is a difference in the attack rate in test and control groups. In this sense then, the observed data are only a sample of all possible observations of this kind.

When the data are looked upon as a sample, the question arises concerning



the extent to which the observed difference between test and control groups may be generalized; i.e., may be considered as being indicative of a real effect of immunization. The reasoning process which leads to this question may be demonstrated by the following hypothetical situation.

**A Hypothetical Situation.** Suppose that immunization really has *no* effect on the attack rate from pertussis, that is, the hypothesis is set up that there is no real difference between test and control groups with respect to attack rates. Under these conditions, if we take a series of samples—that is, conduct a series of experiments like the one reported on above—then, in some cases, the test group will have a lower attack rate than the control group and in some the reverse will occur. The situation may be depicted as follows: Consider that we have a box with a very large number of red and white beads in it. The white beads represent individuals who remain free of the disease and the red beads are those who contract pertussis. Now, suppose we draw a sample from the box to represent the test group. We will get a certain proportion, *P*, of red beads (cases of pertussis). The proportion of red beads in the sample will not necessarily be the same as in the box, although it is an estimate of it. Now, let us draw a second sample,\* to represent the control group. The results may be recorded in line 1 of the following:

Experiment No.	Test Group % Attacked (red beads)	Control Group % Attacked (red beads)	Difference
1	8	13	-5
2	12	10	2
3	14	11	3
4	9	13	-4
.	.	.	.
.	.	.	.
.	.	.	.
k	10	11	-1
Average	P	P	0

It will be noted that line 1 represents the situation as it is usually met in an actual study in which a difference has been observed between test and control groups. In this case, however, *we know that the difference between the two groups can only be due to the operation of chance*, since both groups came from the same box. Reasoning by analogy, it might be perfectly possible in an actual problem to get a difference between test group and control group, purely through the operation of chance rather than because the agent being studied (immunization, in this case) had any effect at all. How, then, shall we discover whether an observed difference is likely to be due to chance or not?

If we were to take samples from the box over and over again, they would differ among themselves as to the proportion of red beads (per cent attacked) and we would begin to get some idea of the extent of this chance variation in the difference between the test and control groups. Lines 2, 3, 4 . . . k in the table show the development of this variation when the experiment is repeated over and over again. Figure 44-1 shows the situation diagrammatically. In the diagram, *p* repre-

\* The beads are replaced in the box after each drawing.

sents the true proportion of red beads (per cent attacked) in the box from which the samples are drawn. It will be noted that the curve for both the test and control groups centers around this value of  $p$  and, therefore, the curve of difference centers around zero.

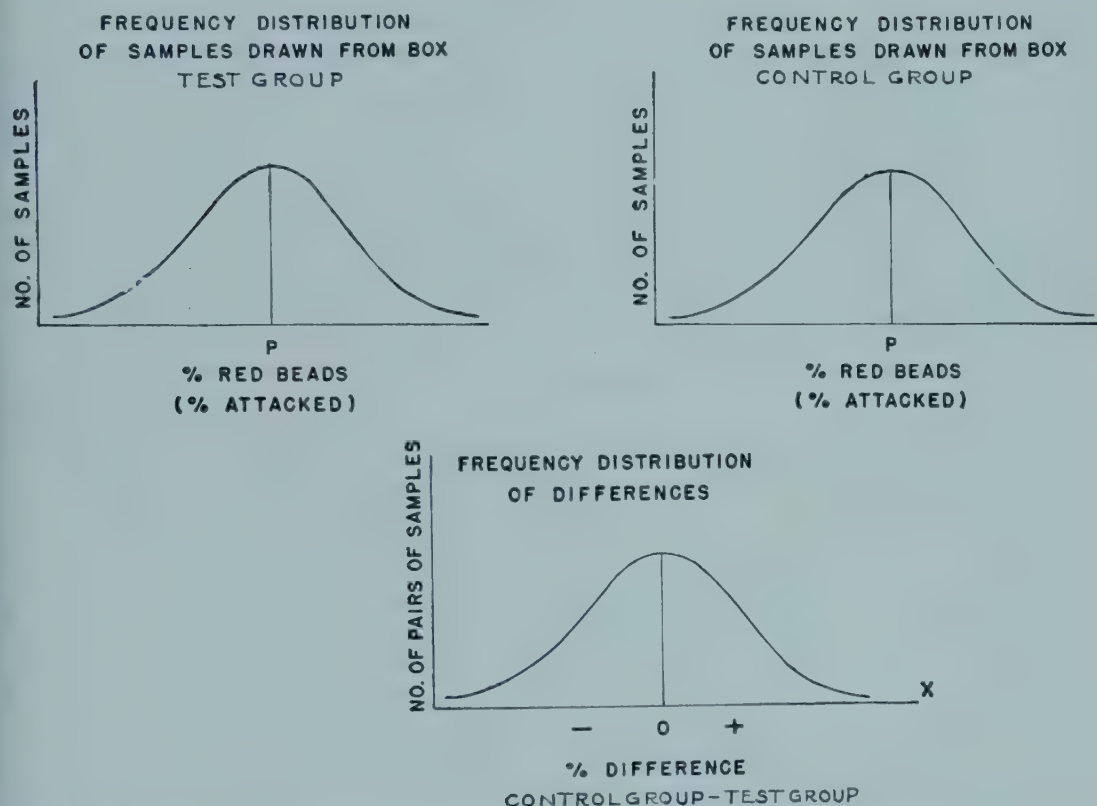


Fig. 44-1. Diagram of variation which would occur on repeated sampling. Hypothetical situation.

Referring to the curve of differences, if we carried out an actual study and obtained a difference of such a magnitude that it fell at the point marked  $X$  in the diagram, which is well outside the extent of variation of most of the differences which would occur as a matter of chance, we would say that the observed difference is unlikely to occur by chance and is probably due to other factors. In other words, the observed difference  $X$  is not consistent with the hypothesis that there is no difference between test and control group. We would then seek an explanation for the observed difference. On the other hand, if the observed difference fell well within the curve of chance variation of the differences, the only conclusion to be drawn is that it could easily occur as a matter of chance, and is, therefore, the kind of difference that would be expected under the hypothesis.

Given any observed difference then, if we know how much it deviates from the center of the curve, we can say whether it falls inside or outside the "ordinary" limits of chance variation and so determine if it is likely to occur by chance. What is needed, therefore, is some index or measure which describes how the curve of chance variation spreads out around the center. This index or measure must possess certain characteristics. It must be able to distinguish between two curves such as are shown in Figure 44-2, panel A, in one of which the observations spread out



quite a bit and in the other of which they are more closely clustered about the center. However, this measure must also have approximately the same value for the two curves shown in panel B of Figure 44-2, which spread out essentially the same way around the center except for an outlying observation on one of the

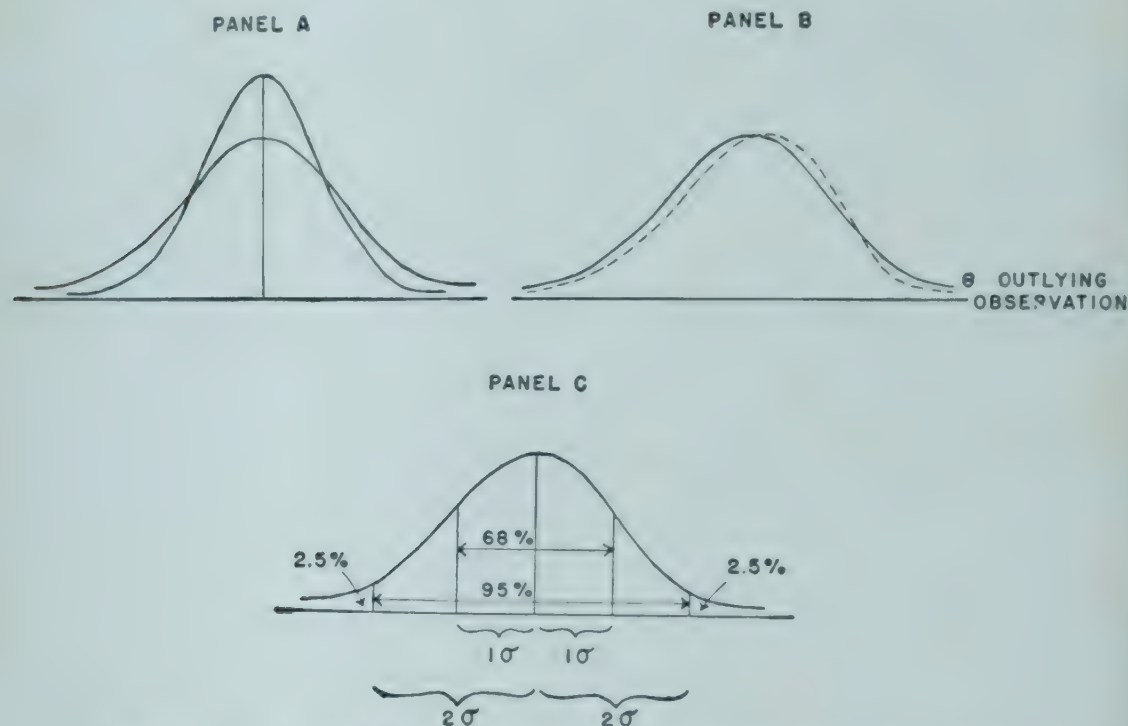


Fig. 44-2. Curves of chance variation and the normal probability curve.

curves. A measure which described the curves in terms of the proportion of the total area within a stated distance of the center of the curve would have these characteristics. When the curve of chance variation approximates the bell-shaped normal probability curve \* such as is shown in the figures, the mathematical characteristics of the curve provide such a measure. It is known as the *standard deviation*.

The standard deviation is the distance out from the center of the curve which must be covered in order to encompass 34 per cent of the total area on either side of the center, or 68 per cent altogether, as shown in panel C of Figure 44-2. It is commonly denoted by the Greek letter  $\sigma$ . It may be seen by referring to panels A and B that this measure meets the requirements laid down above. It is not necessary to go out as far from the center to cover 34 per cent of the total area of one of the curves in panel A as for the other curve. In panel B, it is seen that the value of  $\sigma$  would be essentially the same for the two curves.

The proportion of the total area of the normal curve within a given distance of the center, expressed in standard deviation units, is shown in panel C. Reference to panel C will show how  $\sigma$  may be used to measure the extent of chance variation.

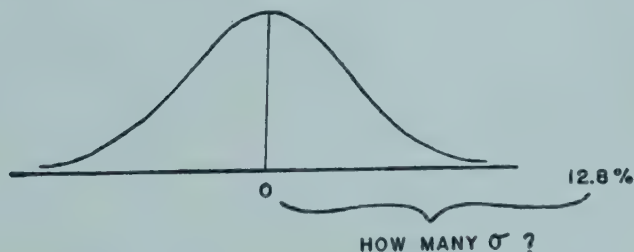
\* Not all curves of chance variation which would be obtained by repeating the observations over and over again are "normal." Usually, though not necessarily, if the number of observations is increased they approach the normal curve or they may be mathematically transformed into a normal curve. When the number of observations in the sample is less than 20, the "poisson binomial" is used to determine the desired probabilities. This procedure is described in any standard statistical textbook.

It may be seen from the diagram that if one goes out two standard deviations on either side of the center, a sizable proportion of the total area of the curve of chance variation is covered—95 per cent, in fact. It follows that, *as a matter of chance*, observations falling further away from the center of the curve than two standard deviations will occur only about five times in 100. If then the observed difference lies outside of two standard deviations, we may say that if there were really no difference in the two sets of observations which are being compared, a difference as great or greater than that observed would occur less than five times out of 100, purely as a matter of chance. These, then, are the betting odds that the observed difference is statistically significant. The dividing line between what is usually considered statistically significant and what is not is purely arbitrary. One may prefer to set the dividing line at three standard deviations, in which case the chances are only one in 100 that an observation will fall outside this distance from the center purely by chance. Ordinarily, the dividing line is placed at two standard deviations.

Table 44-3. Comparison of test and control group as to per cent attacked

Group	Attack	No Attack	Total	% Attacked per Year
Test	52	2,216	2,268	2.3
Control	348	1,959	2,307	15.1
Total	400	4,175	4,575	8.7

**Application to an Actual Problem.** Returning to the pertussis problem, we may summarize the findings of the study in Table 44-3. Such a table is known as a 2 by 2 table, or a *four-fold table*, because there are two categories each way in the table and four primary cells in the table. Is the difference in the attack rate in the test and control groups a real difference, or is it one which might arise by chance even though there was really no difference in the two groups? This question requires an answer before we can generalize these observations to conclude that pertussis immunization reduces the attack rate.



% DIFFERENCE BETWEEN TEST AND CONTROL GROUP

Fig. 44-3. Diagram of problem of determining whether observed difference is likely to be due to chance or not.

The approach to answering the question is as indicated above. We need to know if the observed difference of 12.8 per cent is more or less than two standard deviations away from the center of the curve of differences (see Fig. 44-3).



The curve centers at zero since the hypothesis to be tested is that there is no difference between the two groups, and we wish to determine the extent of chance variation under this hypothesis.

**The Computation of the Standard Deviation of the Curve of Differences.** Each of the three curves in Figure 1 has its own standard deviation. The standard deviation is computed from the formula  $\sigma = \sqrt{\frac{pq}{n}}$ , where  $p$  = probability of occurrence of the event,  $q = 1 - p$ , and  $n$  = size of the sample. If, in our hypothetical example, we knew the true proportion ( $p$ ) of red beads in the box (per cent attacked) we would use this in the formula for the standard deviation. This is unknown, however, and an estimate has to be made from the observed data. Since our hypothesis is that there is no difference in the two groups, the most likely value of  $p$  in the example is that for the total; hence,  $p = .087$ , and  $q = 1 - p = .913$ .

We then have the following formulae:

$$\sigma_t = \sqrt{\frac{pq}{n_t}} \text{ where } n_t = \text{the number of individuals in the test group,}$$

$$\sigma_c = \sqrt{\frac{pq}{n_c}} \text{ where } n_c = \text{the number of individuals in the control group,}$$

and

$$\sigma_{\text{difference}} = \sqrt{\sigma_t^2 + \sigma_c^2} = \sqrt{\frac{pq}{n_t} + \frac{pq}{n_c}} = \sqrt{\frac{.087 \times .913}{2,268} + \frac{.087 \times .913}{2,307}} = .0083$$

Then the observed difference divided by the standard deviation of the difference =  $\frac{.128}{.0083} = 15.4 \sigma$ 's

Thus, the observed difference is 15.4 standard deviations away from the center of the curve of differences (see Fig. 44-3). Since it is far beyond two standard deviations, a difference of this magnitude would occur by chance only once in millions of trials. Other things being equal, then, it appears as though the difference is a real difference which may be attributed to the effect of immunization.

**Interpretation of Results of Tests of Significance.** If a difference is found not to be statistically significant, all that can be said is that since it might easily arise by chance, it is not possible to determine whether the difference was the result of the experiment or not. If, however, the difference is found to be one which is unlikely to occur by chance, an explanation for the difference must be sought. *If the test and control groups are alike in every respect but that being tested*—that is, if all other things are equal—the difference may be attributed to the factor being tested. The reader is referred to the earlier discussion of this point (see page 1311).

In their study of the efficacy of immunization against pertussis, Kendrick and Eldering (1939) compare test and control groups on a number of factors such as age and sex, geographic distribution, family size, incidence of communicable diseases other than pertussis and number of nursing visits. The authors concluded that, for the purposes of their study, the two groups were similar with respect to factors which might influence the attack rate other than immunization. Under these

circumstances, therefore, the fact that the attack rate in the test group was significantly lower than in the control group may be interpreted as indication that immunization conferred some protection.

**The Comparison of Groups which are Classified into More than Two Categories.** The procedure just outlined is adequate for dealing with most situations involving the comparison of rates when the data can be arranged in the form of a four-fold table. Situations often arise, however, in which one or both of the factors to be compared are classified into more than two categories. Such an instance is shown in Table 44-4. The table was designed to examine the question of the rela-

Table 44-4. Distribution of infants born in Vanderbilt University Hospital in 1946, by type of feeding and by pay status of mother

Type of Feeding	Number of Infants				Per Cent of Total in Each Pay Status Group			
	Ward	Low Cost Private	Private	Total	Ward	Low Cost Private	Private	Total
Breast fed only	378 423	206 210	294 245	878	66.0	60.0	49.0	58.9
Artificially fed only	51 58	28 21	40 40	119	9.0	6.0	8.0	8.0
Breast and artificially fed	212 160	116 119	166 215	494	25.0	34.0	43.0	33.1
Total	641	350	500	1491	100.0	100.0	100.0	100.0

Chi square = the sum of  $\left[ \frac{(\text{the theoretical} - \text{observed frequencies})^2}{\text{the theoretical frequency}} \right]$

$$\chi^2 = \sum \frac{(T - O)^2}{T}$$

$$\chi^2 = \frac{(378 - 423)^2}{378} + \frac{(206 - 210)^2}{206} + \frac{(294 - 245)^2}{294}$$

$$+ \frac{(51 - 58)^2}{51} + \frac{(28 - 21)^2}{28} + \frac{(40 - 40)^2}{40}$$

$$+ \frac{(212 - 160)^2}{212} + \frac{(116 - 119)^2}{116} + \frac{(166 - 215)^2}{166}$$

$\chi^2 = 43.610$

d.f. = 4

n' = 5

P = < .000000

tionship between the economic status of the mother and the nursing of the baby. It may be seen that ward mothers seem to breast feed their babies more frequently than mothers on the private or low cost private service of the hospital. Is this really true, or could differences like those seen in the table readily occur as a



matter of chance? The general reasoning process which leads to this question and to its answer is the same as that which pertains to data which are classified into a four-fold table.

The hypothesis is set up that there is no real difference among the several pay status groups with respect to the method of feeding the baby. Under this hypothesis we might expect each group to show the same percentage breast fed, except for chance variation, as the total; namely, 58.9 per cent. Thus, in the ward group we would expect 58.9 per cent or 378 of the 641 ward babies to be breast fed, if the data are consistent with the hypothesis. Similarly, we would get an expected number for each cell of the table. These expected numbers are shown in italics in the table. The problem then is to determine whether the difference between the observed frequencies and those expected under the hypothesis are likely to occur as a matter of chance. Although this is the same type of question that arises with respect to data in the four-fold table, the technical procedure for answering it is slightly different and goes under the name of the Chi-square ( $\chi^2$ ) test. The computation of  $\chi^2$  is shown below Table 44-5. Its value is 43.610. Reference to a table \* of the probability of obtaining a particular  $\chi^2$  by chance alone shows that such a value would occur less than one time in a million purely through the operation of chance. It is very unlikely, therefore, that the hypothesis that there is no difference among the several groups is correct. We must now seek an explanation for the observed differences.

MEASUREMENT DATA

The discussion thus far has been largely in terms of attribute data (see page 1324) and it has been indicated that most of the reasoning about such data revolves around comparison of rates or ratios of one kind or another. In dealing with measurement

Table 44-5. Frequency distribution of weight at birth of 569 white first-born infants delivered at Vanderbilt University Hospital, 1941-1942

Birth Weight in Grams	Number of Infants
1,000-1,499	1
1,500-1,999	1
2,000-2,499	10
2,500-2,999	81
3,000-3,499	239
3,500-3,999	173
4,000-4,499	53
4,500-4,999	11
TOTAL	569

\* A table showing this probability may be found in Pearson (1948). It is entered with the calculated value of  $\chi^2$  and the value shown as  $n^1$  in the computation under Table 44-5.  $n^1$  is one more than the number of independent cells in the table. The number of independent cells is also known as the degrees of freedom (d.f.) and is the number of cells which can be filled in independent of the totals.

data, however, the reasoning is in terms of certain characteristics of the frequency distribution of these measurements. The general principles, however, are the same.

The approach to measurement data is best illustrated by a specific example. Table 44-5 shows the distribution of weight at birth of 569 first-born white infants delivered at Vanderbilt Hospital in 1941-1942. The data are presented graphically in Figure 44-4. It has been indicated earlier that it is unlikely that we will be inter-

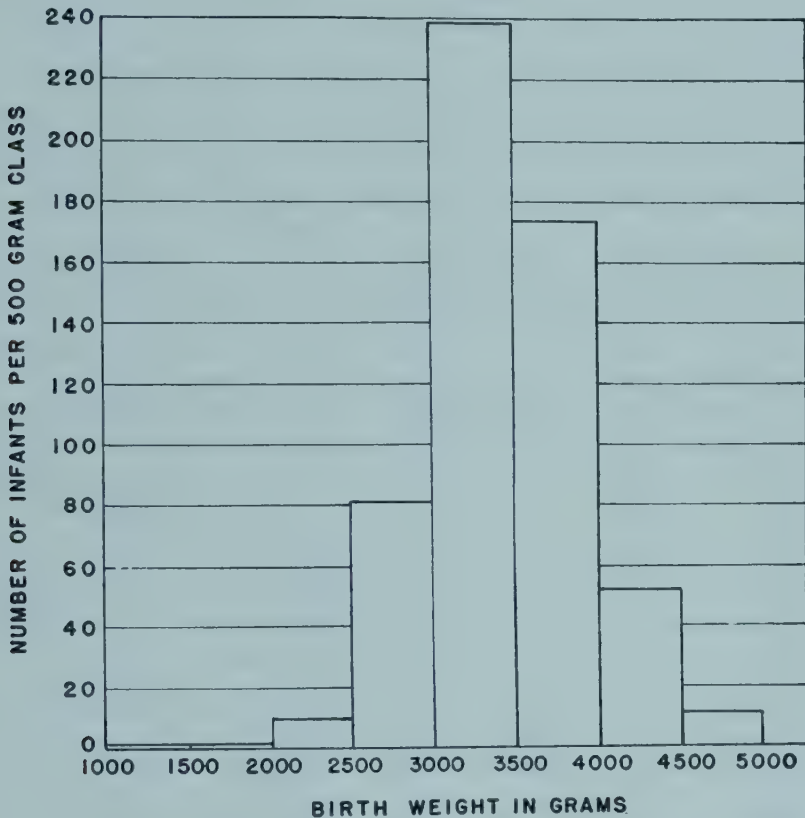


Fig. 44-4. Frequency distribution of birth weights of 569 white first-born infants delivered at Vanderbilt University Hospital, 1941-1942.

ested in these data solely for their own sake, but rather for the knowledge they can provide about white first-born babies in general. For this reason, it is desirable to describe the data in terms of fairly general applicability. Figure 44-4 suggests that this might be done by describing where the distribution centers and how the observations spread out around the center.

**Describing the Symmetrical Frequency Distribution.** When the data are distributed in approximately the bell-shaped normal curve, the *arithmetic mean* \* is used as an indication of where the observations center on the scale. The arithmetic mean of the data in Table 44-5 is 2,439.0 grams. The measure of the variability of the observations around the mean which is used is the *standard deviation*. Its value for these data is 494.5 grams. (See page 1333 for the procedure used in computing these statistical measures.)

\* The arithmetic mean is ordinarily referred to as the average, but since there may be many kinds of averages, the term arithmetic mean is preferred.



How can these characteristics of the observed frequency distribution—the mean and the standard deviation—be used to yield information about the birth weights of first-born white infants in general? If these observations are thought of as a sample from the “population” (or box, as on page 1324) of all first-born white infants, and if we then take repeated samples from this population, the samples will vary among themselves purely as a matter of chance. The measures of central tendency will also vary from sample to sample so that we will have a distribution of the sample means which will vary around the true mean of the population from which the samples are drawn \* (see page 1324). The measure of the extent of the sampling or chance variation of the means will be given by the *standard deviation of the distribution of means*. This is obtained by dividing the standard deviation of the individual observations in the population from which the sample is drawn by the square root of the number of observations in the sample. Using  $\sigma$  to represent the standard deviation, we may write:  $\sigma_m = \frac{\sigma_{\text{population}}}{\sqrt{n}}$  where  $n$  is the number of observations in the sample. The formula shows that for a specific degree of variation of the individual observations in the population, the larger the size of the sample, the less the variability of the sample mean. Since  $\sigma_{\text{population}}$  is unknown, the standard deviation of the observed data is substituted for it.† For this example,

then,  $\sigma_m = \frac{\sigma_{\text{sample}}}{\sqrt{n}} = \sqrt{\frac{494.5}{569}} = 20.7$  grams. The value obtained by this formula is usually referred to as the *standard error* of the mean. Since the distribution of means may ordinarily be described by a normal curve, a standard error of 20.7 grams tells us that if we were to take repeated samples like the one in Table 44-5, 95 per cent of the means of these samples would vary within  $\pm 2 \times 20.7$  grams = 41.4 grams of the true mean of the population. Thus, we obtain some notion of the confidence which we may place in the observed mean as an estimate of the true mean.

Since the standard deviation of the observed data has been used as an estimate of the standard deviation of the individuals in the population from which the sample is drawn, the statement may also be made that if the observed sample were repeated over and over again, the chances are 95 out of 100 that the weights of individual infants would not differ from the true average weight in the population by more than  $2 \times 494.5 = 989.0$  grams.

In summary, then, if the mean and standard deviation of a frequency distribution which may reasonably be described by a normal curve are known, the standard error of the mean may be calculated and from these three measures, one can obtain a notion of how much one may rely on any generalization from the observed data to the population from which it is drawn. These statements only hold, however,

\* Bradford Hill (1950) gives the results of an experiment showing the actual variation of the means from sample to sample.

† The reader should note that just as the means will vary from sample to sample, so will the standard deviations. However, the use of the observed  $\sigma$  as an estimate of the population  $\sigma$  is not likely to introduce any serious errors, provided the size of the sample is sufficiently large—preferably larger than 30. The reader is referred to standard texts for procedure when the sample size is less than this.

when the sample is representative of the population to which it is expected to generalize. If, for example, white male first-born infants delivered at Vanderbilt Hospital should be selected in some way which would tend toward a disproportionate number of infants with low birth weights—for instance, if their mothers all had complications during pregnancy—generalization to all white male first-born infants would not be valid (see page 1312 and Densen, 1949).

**Procedure for Computing the Mean and Standard Deviation of a Frequency Distribution.** The basic definitions are as follows:

The *mean* is the sum of the observations divided by the number of observations.

$$\text{Formula: } \bar{X} = \frac{\Sigma(X)}{n}, \quad (1)$$

where  $X$  is an individual observation,  $n$  is the number of observations,  $\Sigma$  means “the sum of” and  $\bar{X}$  represents the mean.

The *standard deviation* is the square root of the sum of the squared deviations from the mean divided by the number of observations minus one.

$$\text{Formula: } \sigma = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n - 1}}, \quad (2)$$

where the symbols have the same meaning as in the formula for the mean and  $\sigma$  represents the standard deviation.

**APPLICATION TO UNGROUPED DATA.** Suppose the following observations of hemoglobin on 10 individuals:

Hgb. in gm. Individual per 100 ml. of blood			
No.	X	$(X - \bar{X})$	$(X - \bar{X})^2$
1	14.3	—2.24	5.02
2	15.1	—1.44	2.07
3	15.7	—0.84	0.70
4	16.2	—0.34	0.11
5	16.5	—0.04	0.00
6	16.9	+0.36	0.13
7	17.3	+0.76	0.58
8	17.6	+1.06	1.12
9	17.8	+1.26	1.59
10	18.0	+1.46	2.13
Sum	165.4	0	13.45

$$\text{Mean } \bar{X} = \frac{\Sigma(X)}{n} = \frac{165.4}{10} = 16.54 \text{ gm. per 100 ml.}$$

$$\text{Standard deviation } \sigma = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n - 1}} = \sqrt{\frac{13.45}{9}}$$

$$= \sqrt{1.49} = 1.22 \text{ gm.}$$

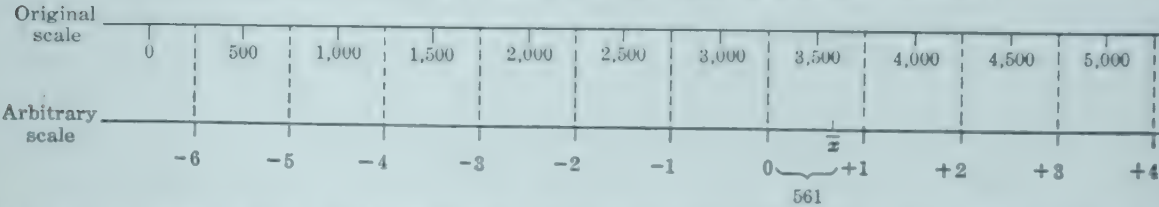


APPLICATION TO GROUPED DATA. When the number of observations is large the procedure used for ungrouped data is very time consuming. The entire process may be considerably simplified by grouping the observations and employing a device known as an "arbitrary origin." The computation may be illustrated with the data presented in Table 44-5, which is reproduced here.

Frequency distribution of weight at birth of 569 white first-born infants delivered at Vanderbilt University Hospital, 1941-1942

Birth Weight in Grams	Number of Infants	Arbitrary Scale		
X	f	x	xf	x <sup>2</sup> f
1,000-1,499	1	- 4	- 4	16
1,500-1,999	1	- 3	- 3	9
2,000-2,499	10	- 2	- 20	40
2,500-2,999	81	- 1	- 81	81
3,000-3,499	239	0	0	0
3,500-3,999	173	+ 1	173	173
4,000-4,499	53	+ 2	106	212
4,500-4,999	11	+ 3	33	99
TOTAL	569		+ 204	630

The effect of using an arbitrary origin may be shown diagrammatically.



It is seen that the origin is shifted so that zero on the arbitrary scale corresponds to 3,250 grams on the original scale and one unit on the arbitrary scale corresponds to 500 grams on the original scale. As its name indicates, the arbitrary origin may be placed anywhere in relation to the original scale. However, the computation is facilitated by placing it somewhere near the center of the distribution which is usually in the class with the greatest frequency.

The computation is now carried forward so that the mean and standard deviation are first determined in the units of the arbitrary scale and then converted back to the original scale.

Mean on the arbitrary scale  $\bar{x} = \frac{\sum xf}{n}$

Equivalent to Formula 1

$$= \frac{204}{569} = .358$$

Standard deviation on the arbitrary scale  $\sigma_x = \sqrt{\frac{\sum x^2 f}{n}}$

Equivalent to Formula 2 \*

$$= \sqrt{\frac{630}{569}} = \sqrt{1.11}$$
$$= 1.05$$

\* The formula here is equivalent to formula 2 except that we have divided by n rather than n-1. When the number of observations is greater than 30, the use of n rather than n-1 does not introduce any significant error.

Referring to the diagram, it is seen that a mean of .561 on the arbitrary scale corresponds to a little more than 3,500 gm. on the original scale. This may be expressed by formula as:

Mean  $\bar{X}$  = Arbitrary origin +  $i \left( \frac{\sum xf}{n} \right)$ , where  $i$  represents the size of the class interval.

$$\begin{aligned}\bar{X} &= 3,250 \text{ grams} + 500 (.358) \\ &= 3,250 + 179 = 3,429.0 \text{ gm.}\end{aligned}$$

The standard deviation is shifted back to the original scale by making a correction for the fact that the deviations were measured from the arbitrary origin rather than the mean and multiplying by the size of the class interval. By formula this is:

$$\sigma_x = i \sqrt{\frac{\sum x^2 f}{n} - \left( \frac{\sum xf}{n} \right)^2}$$

It will be noted that the second term under the square root sign is simply  $\bar{x}^2$ . Thus,

$$\begin{aligned}\sigma_x &= 500 \sqrt{\frac{630}{569} - (.358)^2} = 500 \sqrt{1.11 - .13} \\ &= 500 \sqrt{.98} = 500 (.989) = 494.5 \text{ gm.}\end{aligned}$$

The values of the mean and standard deviation obtained by this procedure are those presented on page 1331.

**Comparing Frequency Distributions.** As in the case of attributes, we frequently wish to compare one set of measurement data with another. For instance, we may wish to compare the average weight at birth of the white first-born infants at Vanderbilt Hospital with those of later birth order. In a sample of 320 infants of birth order later than the first, the mean weight was found to be 3,525 grams—96 grams heavier than the average weight for the sample of 569 first-born babies. Do the infants born to multipara mothers really weigh more on the average than the babies of primipara mothers, or could a difference of 96 grams easily occur as a matter of chance although no difference exists in the population from which the samples are drawn? This is exactly the kind of question which was asked about the difference in the percentage attacked in the test and control groups for the pertussis immunization problem and it is answered according to the same principles.

In the pertussis problem it was found necessary to determine how far away from the center of the distribution of differences the observed difference fell and to express this distance in terms of standard deviations (see Fig. 44-3). This information could then be converted into a statement as to whether the observed difference is likely to occur by chance or not. In order to do this the standard error of the distribution of differences had to be calculated. The standard error of the difference between two means \* is given by  $\sqrt{(S.E._{m_1})^2 + (S.E._{m_2})^2}$  where  $S.E._{m_1}$  stands for the standard error of the first mean and  $S.E._{m_2}$  for the standard error of the second mean. The standard error of the mean for first-born infants was found to be 20.7 grams. For the infants of later birth order the standard error of the mean is given by substituting in the formula  $S.E._m = \frac{\sigma_{\text{sample}}}{\sqrt{n}} = \frac{560}{\sqrt{320}} = 31.3 \text{ grams.}$

\* When the two sets of data are independent of each other.



The S.E. of the difference then is  $\sqrt{(20.7)^2 + (31.3)^2} = 37.5$  grams. The observed difference of 96 grams is therefore 2.6 times the standard error of the difference. Differences of this order will occur about one time in 100 as a matter of chance. If one considers differences which will occur less than five times out of 100 by chance as unlikely to be due to chance, then the observed difference of 96 grams is "statistically significant." It should be remembered, however, that "statistically significant" is just a phrase, and the dividing line of five times out of 100 is entirely arbitrary. The real question is one of the probabilities involved and it is up to the worker to interpret a probability such as one in 100 as "likely" or "unlikely" to occur by chance. If the particular case falls on what he considers to be the borderline between these choices, the only way out of the dilemma is to gather more data.

One may compare frequency distributions on other characteristics than where they center, such as the variability of the observations. For example, is the birth weight of first-born babies more or less variable than those of later birth order? The same principles hold in answering this question as that concerned with differences between proportions or differences between means. These principles apply when we are dealing with fairly large samples. The reader is referred to Yule and Kendall (1948) for details concerning comparison of distributions with respect to other characteristics than the mean and also for a discussion of the methods of dealing with small sample data.

**Describing Asymmetrical Distributions.** When the data do not form a symmetrical distribution the mean and standard deviation, respectively, are not good indices of the centering and scatter of the observations. The mean is too readily affected by an occasional extreme observation and the interpretation of the standard deviation depends upon having a normal curve. Under these circumstances, the median and the quartiles are used to describe the distribution. The data in Table 44-6 are illustrative of a distinctly asymmetrical distribution. The data are of particular interest in connection with the control of industrial dust hazards and they may be used to demonstrate the meaning of the median and the quartiles.

The median is that value on the scale of classification which divides the observations in half. Since there are 154 observations shown in the table, the median is the value of the 77th observation, if the observations were arranged in order from the smallest size particle to the largest. If the observations in the table are cumulated as shown in the last column it is seen that 60 particles have a size less than 3.30 microns and 80 have a size less than 4.40 microns. Since the observation in which we are interested is the 77th, the median value must, therefore, be between 3.30 and 4.40 microns. It is readily found if it is assumed that the 20 observations in this class are evenly distributed over the class.\* Since up to 3.30 microns we already have 60 observations, we need 17 more to come up to the 77th observation. This will take us nearly, but not quite, to 4.40 microns. In fact, if we take  $\frac{17}{20}$  of the class size of 1.10 microns and add this to the beginning of the class we will have a fairly good estimate of the median. Thus, the median is equal to  $3.30 + \frac{17}{20}(1.10) = 4.24$  microns. This means that half the dust particles have a

\* This is not an unreasonable assumption if the width of the class—in this case 1.10 microns—is not too great.

Table 44-6. Size of dust particles in the air

Particle Size (in microns)	Number of Particles	Cumulated Number of Particles
1.10-1.19	28	28
2.20-3.29	32	60
3.30-4.39	20	80
4.40-5.49	15	95
5.50-6.59	14	109
6.60-7.69	8	117
7.70-8.79	9	126
8.80-9.89	5	131
9.90-10.99	4	135
11.00-12.09	5	140
12.10-13.19	3	143
13.20-14.29	2	145
14.30-15.39	1	146
15.40-16.49	0	146
16.50-17.59	2	148
17.60-18.69	0	148
18.70-19.79	1	149
19.80-20.89	0	149
20.90-21.99	2	151
22.00-23.09	0	151
23.10-24.19	0	151
24.20-25.29	1	152
25.30-26.39	2	154
Total Particles	154	

Adapted from Drinker and Hatch, *Industrial Dust*, 1st ed., New York, McGraw-Hill Book Co., 1936, Table 24, p. 148.

size of less than 4.24 microns and half have a size greater than this. The mean of this same distribution is 5.85 microns, which is considerably above the value above and below which half the observations fall.

The quartiles are computed in the same manner as the median. The first quartile,  $Q_1$ , is the value below which 25 per cent and above which 75 per cent of the observations fall. It is, therefore, the value of the 38.5th observation \* (154 divided by 4). Referring to the table, it is seen that the value of  $Q_1$  is somewhere between 2.20 microns and 3.30 microns. Since up to 2.20 microns we have 28 observations, 10.5 more are needed. This brings us up to  $2.20 + \frac{10.5}{32}(1.10)$  microns = 2.56 microns. The value of the observation below which 75 per cent of the observations fall and above which 25 per cent fall is  $Q_3$ . This is the 115.5th observation, which means that  $Q_3$  lies somewhere between 6.60 and 7.70 microns. Up to 6.60 microns there are 109 observations and there are 8 observations in the class 6.60 = 7.70 microns. Hence,  $Q_3 = 6.60 + \frac{6.5}{8}(1.10)$  microns = 7.49 microns.

It will be noted that 50 per cent of the observations lie between  $Q_1$  and  $Q_3$  or, in this case, between 2.56 and 7.49 microns.

\* This illustrates the point that the calculation of the median really assumes continuous distribution.



The standard errors of the median and quartiles as well as a discussion of their use and limitations in generalizing the observations may be found in Yule and Kendall (1948).

**Association.** In the discussion of the effect of immunization on the occurrence of whooping cough, a four-fold table of the following form was set up (see Table 44-3):

Group	Attack	No Attack	Total	% Attacked
Test				
Control				
Total				

The per cent attacked in the control group was compared with that in the test group and it was determined that the difference was unlikely to occur by chance. Other things being equal, it was concluded that the attack rate varied with whether or not an individual was immunized. In other words, the attack rate was associated with immunization. This process can be more generally described by writing the four-fold table as follows:

Group	A	Not A	Total	% A
B	a	b	a + b	$\frac{a}{a + b}$
Not B	c	a	c + a	$\frac{c}{c + d}$
Total	a + c	b + a	a + b + c + d	$\frac{a + c}{a + b + c + d}$

Whenever  $\frac{a}{a + b}$  differs from  $\frac{c}{c + d}$  by more than would be expected as a matter of chance, we say that A is associated with B—that is, varies with the presence or absence of B.

The comparison of attributes usually takes the form indicated in the above table, although the number of categories may be extended as indicated in the discussion on page 1329. When we deal with measurement data the form of the table changes, depending on whether B alone is a measured variable or both A and B are measured variables. An example of the first case is given by the comparison of the birth weights of first-born infants and later-born infants (see page 1335). In this case the table takes the form:

B Grouped Values of Measured Variables	A	Not A
Group 1		
2		
3		
4		
5		
6		
.		
.		
.		
Total		
Arithmetic Mean		

Here A represents the first-born infants and Not A represents those of later birth order. The measured variable is the birth weight. Group 1 of the birth weights, for example, is the group of weights from 1,000 through 1,499 grams. We say that the measured variable is associated with whatever A represents if the difference between the mean value of the measured variable for A and that of Not A is unlikely to occur by chance and if A and Not A do not differ in other respects.

When both A and B are measured variables the table takes the following form:

Grouped Values of Measured Variable B	Grouped Values of Measured Variable A				Total	Arithmetic Mean
	Group a	Group b	Group c	....		
Group 1						$M_1$
Group 2						$M_2$
Group 3						$M_3$
Group 4						$M_4$
.						
.						
.						
Total						$M_A$
Arithmetic Mean	$M_a$	$M_b$	$M_c$		$M_B$	

An example of this form is shown in Table 44-7. The average cancer death rate without taking account of the diabetes rate ( $M_{11}$ ) is 113.3 per 100,000 population. If the cancer death rate were not associated with the diabetes death rate—that is, did not vary when the diabetes rate varied—it would have the same value \* in each specific diabetes death rate group. In terms of the symbols in the

\*Except for chance variation.



Table 44-7. Death rates from diabetes and from cancer and other malignant tumors in each state of the United States and the District of Columbia in 1940

Diabetes Death Rate											
	6-9	10-13	14-17	18-21	22-25	26-29	30-33	34-37	38-41	Total	Average Diabetes Rate
55-64	1	3	1							5	12.0
65-74		2								2	12.0
75-84		1	5	1						7	16.0
85-94			3	1		1				5	19.2
95-104				1	1					2	22.0
105-114				2						2	20.0
115-124			1			2				3	24.0
125-134					1	4	1	1		7	29.1
135-144					1	2	2	1		6	30.0
145-154					1		2	2		5	32.0
155-164							1		2	3	37.3
165-174						1		1		2	32.0
Total	1	6	10	5	4	10	6	5	2	49	23.8
Average Cancer Rate	60.0	66.7	85.0	98.0	130.0	130.0	145.0	148.0	160.0	113.3	
	$M_A$	$M_B$	$M_C$							$M_B$	$M_A$

Death Rate from Cancer and Other Malignant Tumors

table,  $M_a$  would equal  $M_b = M_c$ , etc.  $= M_B$ . By the same reasoning,  $M_1$  should equal  $M_2 = M_3$ , etc.  $= M_A$  if the diabetes rate were not associated with the cancer rate. Inspection of Table 44-7 shows that this is not so, but that as the diabetes death rate increases, the average cancer death rate also tends to increase. It appears then as though the value of the cancer death rate is associated with the diabetes death rate. It may also be seen that as the death rate from cancer increases, the average death rate from diabetes also increases, so that there is an association of the diabetes death rate with the cancer death rate. In general, then, it appears that the states with high cancer death rates also have high diabetes death rates, and vice versa. Having demonstrated that such an association exists, the investigator should seek the reasons for it.

A table such as Table 44-7 is known as a correlation table. The procedure just outlined may be used to investigate the existence of association. The question of the *degree* of association requires more advanced technics for its solution, and the reader is referred to Bradford Hill (1948) or Yule and Kendall (1948) for a consideration of this under the general heading of *correlation*. The reader's attention is called, however, to the similarity of the procedure as applied to Table 44-7 with that discussed under the heading of specific rates (see page 1316).

**Summary.** In order that the details presented in the previous paragraphs may be placed against a proper background, a brief summary is desirable. The study of man and his responses to his total environment, particularly as they are related to the phenomena of health and disease, is essentially the study of variation. The statistical method is a powerful tool for the investigation of this variation. The first and, in many respects, the most important step in undertaking such a study is a clear statement of the problem because the statement of the problem determines the kind of data to be collected and the manner in which this is done. When the data have been collected, they must be systematically organized or tabulated so as to bring out the interrelationships among items; i.e., to show the variation of the phenomenon being studied when classified in different ways. The process of classification results in a recognition of two types of data—attribute data and measurement data. Analysis, which is essentially comparison of one set of data with another, is made by means of rates or ratios for attribute data and by means of certain characteristics of the frequency distribution, such as averages and measures of variation, for measurement data. Since the observed material is almost always expected to serve as the basis for generalization, one must consider how much the observed data may be expected to vary if additional samples were taken—that is, one must consider the reliability of the data as a basis for generalization. This requires knowledge of the extent of sampling variation, and ways of measuring this are presented.

The most involved analysis has little value unless it helps to throw light on the initial question. It cannot do this unless the initial question is carefully stated since, if it is not, the analysis is aimless. For this reason the investigator and the statistician should work as a team in the formulation of the question and in the planning of the analysis. One should regard the statistical consultant in the same way as the general practitioner may regard the specialist. He must have sufficient knowledge of the work of the specialist to know when to call upon him for help. This chapter has attempted to provide information on the principles of statistical



reasoning so as to permit the investigator to recognize the elements of a statistical problem and to enable him to consult the trained statistician when he needs to do so.

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## THE HEALTH OF THE POPULATION

PAUL M. DENSEN, Sc.D.

**Introduction.** The maintenance of health and the control of disease in the population require that we know how much disease there is, where it is and, if possible, why. Insofar as we can answer these questions we will be able to define the problems with which we are confronted, to plan the attack upon them and to evaluate the effectiveness of the attack. The chapter on statistical reasoning has dealt with the general principles by which such questions are answered. The present chapter sets forth some of the knowledge of the health of the population which has been gained through the application of these principles.

## THE POPULATION

If we are to study man in relationship to his environment, particularly with reference to the influence of that environment upon health, it is essential that we have knowledge of how that relationship varies with the characteristics of the population. Does the relationship vary with age, sex, race, occupation, etc.? Such questions require that we be able to classify the population into the categories mentioned. We may then study how changes in these characteristics may modify the health problems with which we have to deal, and, conversely, examine the influence of changes in the health of the population on these characteristics. It is pertinent, therefore, that we inquire into the source of information about populations and their trends.

**Source of Data.** The principal source of information regarding the population is the census. In the United States, censuses of the entire population are provided for in the Constitution and one has been taken every 10 years since 1790.

An indication of the kind of information available from a census is afforded by the following condensed list of items included in the 1950 census of population and housing.

1. **PERSONAL DATA:** Age, race, sex, marital status, highest grade of school completed, place of birth, citizenship, place of residence (city, town, village, or rural), employment status (for persons 14 years old and over), occupation by industry and class of worker, income in the previous year, certain data concerning migration, service in the armed forces and certain information concerning the number of children borne by each married woman.

2. **HOUSING DATA:** Home owned or rented and value of home or rental, the number of rooms, information concerning sanitary facilities and water supply, the



cost of utilities; if the home is rented, whether it is furnished or unfurnished and the cost of utilities; if owned, whether the property carries a mortgage and the market price, etc. Not all these data are obtained for all persons. Some of the information is obtained on a sample basis, a procedure instituted for the first time in the 1940 census.

Most of the types of data collected in a census are of interest to the health worker in one way or another. For example, the data on rental value of home, etc., are of interest in relation to the problem of housing and health, a subject coming in for increasing study.

**Population Estimation in Inter-Censal Years.** In order to study trends in birth rates, death rates, morbidity rates, etc., in years between censuses, it is essential that there be available some estimate of the size of the population in the area for which the rate is being computed. Such estimates may be made in a variety of ways. Most of them represent an extrapolation of past experience, either graphically or by the use of some mathematical expression to represent the growth pattern of the population. Among this latter group are the "arithmetic" method, which assumes that the population increases by a constant amount in each time period, and the "geometric" method in which the assumption is that the percentage increase is constant. These methods have the inherent difficulty that they permit the population to increase indefinitely, although for short periods this problem is usually not troublesome. Another method which is often used employs the "logistic" curve, which takes account not only of past growth of the population, but also of the possible presence of an upper limit to this growth. A description of the application of these methods may be found in Smith (1948) and Pearl (1940).

The Census Bureau at the present time does not use any of these methods directly to estimate state and local populations. It employs a procedure which attempts to estimate the net migration to or from an area from a knowledge of changes in elementary school enrollment plus consideration of the births and deaths occurring in the area and data on individuals in the armed forces. The method is fully described and compared with other methods by Shryock and Lawrence (1949).

In addition to estimating the population in state and local areas as just described, the Census Bureau also takes special censuses of local areas from time to time either as a complete count or on a sampling basis.

The reader will find in the tabular arrangement in Table 45-1 specific sources in which population data are presented.

**Population Growth and Characteristics.** Study of these various sources of information concerning the population reveals several trends in the characteristics of the population which are of great significance in relation to the nature of the medical and public health problems of the present and of the future. The major trends are the following:

1. **DECLINE IN THE RATE OF GROWTH OF THE POPULATION.** The first census in 1790 recorded a population of almost 4,000,000 for the continental United States. Preliminary estimates based upon the 1950 census indicate that the population has grown to nearly 150,500,000. The growth of the population between these two dates has been by no means uniform. Up to 1860, the rate of increase per decade was well over 30 per cent. Thereafter the rate declined somewhat until in

the period 1930-1940 it was only 7.2 per cent. There is some evidence of a rise in the decade 1940-1950 to about 1.4 per cent per year as compared with 0.7 per cent per year in the previous decade.

2. AGING OF THE POPULATION. Partly as a result of the decreased rate of growth of the population and partly as a consequence of the disproportionately large drop in the death rate of infants and children, there has been a steady increase in the proportion of the population in the older ages. In 1900, half the population was less than 22.9 years of age, whereas in 1940 the corresponding median age was 29.0 years. This aging of the population may be seen in Figure 45-1, which shows the proportion of the population age 60 and over from 1890 to 1940.

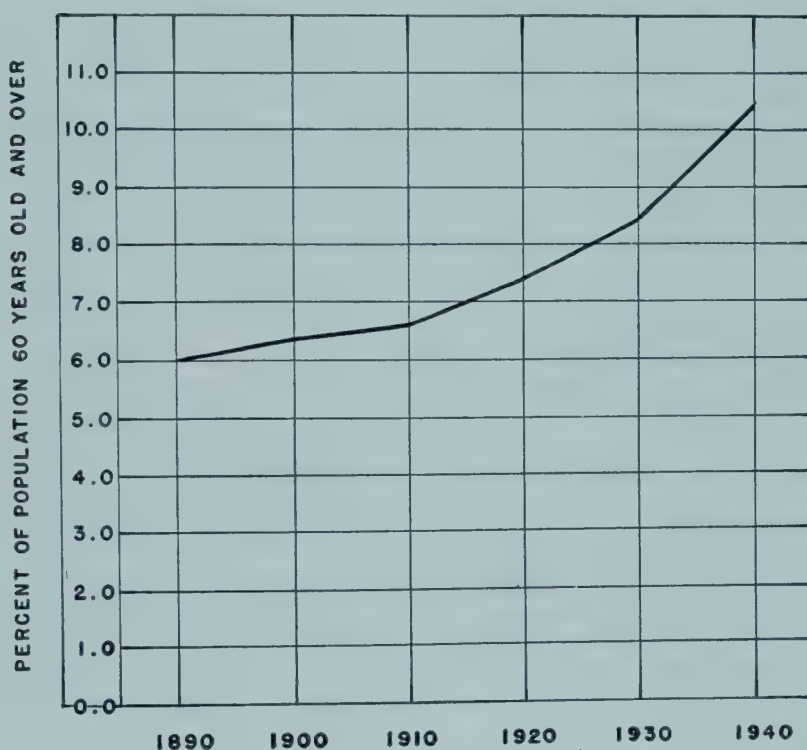


Fig. 45-1. Per cent of the population of the United States 60 years of age and over, 1890-1940.

The increase in the proportion of older persons in the population results in increasing emphasis on the health problems of such persons, such as the cardiovascular-renal diseases and cancer. However, it has been suggested (Reed, 1948) that research in the problems of this age group of the population would profit from a consideration of the well individual rather than being directed almost solely toward the sick individual (see pages 1310 to 1312 in Chapter 44); that is, that preventive programs must approach the problem from "a population base rather than on a base of illness."

3. INDUSTRIALIZATION OF THE POPULATION. Increasing industrialization is a characteristic of modern civilization. This industrialization has brought with it its own peculiar occupational hazards which have given rise to the development of medical services within industry which, within recent years, have been concerned not only with the treatment of occupational illness but also with the whole problem



Table 45-1. A partial list of sources of population and vital statistics data  
(An X under the type of data indicates that such data can be found in the publication)

Organization and Publication	Type of Data			
	Population	Nativity	Mortality	Morbidity
<b>Bureau of the Census:</b>				
1. Reports on the Census of the U. S.	X			
2. Current Population Reports Contain data on population numbers and characteristics, estimated housing, and the labor force on a current basis	X			
3. Statistical Abstract of the U. S.	X	X	X	X
4. Statistical Abstract Supplements				
a. Historical Statistics of U. S., 1789-1945	X	X	X	X
b. County Data Book Contains data for each county and metropolitan area	X	X	X	
c. Cities Supplement Contains selected data for 397 cities	X	X	X	
<b>U. S. Public Health Service:</b>				
1. Public Health Reports Weekly			X	X
2. Supplement to the Public Health Reports (Since 1942 data incorporated in No. 1) Numbers titled (Notifiable Diseases)				X
3. Public Health Bulletin Numbered series of monographs on various subjects, some dealing with incidence and prevalence of disease			X	X
4. Vital Statistics of the U. S. Annually since 1937		X	X	X
5. Mortality Statistics Annually 1900-1936			X	
6. Birth, Stillbirth and Infant Mortality Statistics Annually 1915-1936		X	X	
7. Vital Statistics Rates in the U. S. 1900-1940		X	X	
8. Monthly Vital Statistics Bulletin		X	X	
9. Current Mortality Analysis Monthly			X	
10. Vital Statistics Special Reports Special studies and state statistics		X	X	
11. Weekly Morbidity Report				X
12. Weekly Mortality Index			X	
<b>Individual States and Counties:</b>				
1. Annual Reports	X	X	X	X
2. Monthly Reports	X	X	X	X
<b>United Nations:</b>				
1. Series A—Population Reports A series of monographs	X			

Table 45-1 (cont.). A partial list of sources of population and vital statistics data

Organization and Publication	Type of Data			
	Population	Natality	Mortality	Morbidity
2. Studies of census methods— monographs	X			
3. Statistical Papers—Series A Popula- tion and Vital Statistics Reports	X			
4. Demographic Yearbook	X	X	X	
<b>World Health Organization:</b>				
1. Epidemiological and Vital Statistics Report		X	X	X
2. Technical Report Series Monographs, some dealing with in- cidence and prevalence of specific diseases			X	X
3. Weekly Epidemiological Report By the Pan American Sanitary Bureau regional office of WHO			X	X
<b>Registrar-General for England and Wales:</b>				
1. Annual Statistical Review of England and Wales	X	X	X	X
<b>Medical Research Council of Great Britain:</b>				
1. Special Report Series Monographs on various subjects some of which deal with the inci- dence and prevalence of disease			X	X
<b>Office of Population Research, Princeton University, and Population Association of America:</b>				
1. Population Index A bibliographic index to popula- tion and vital statistics literature. Also contains summary tables on population and vital statistics	X	X	X	

of the worker and his relationship to his working environment (Division of Industrial Hygiene, 1943).

Apart from the problems associated with specific health hazards in industry, the concentration of large groups of the population in particular industries has led to attempts to "approach community health or comprehensive medical care of the families of industrial workers by way of the industry itself" (Reed, 1948). An outstanding example of such an attempt is the Welfare Fund of the United Mine Workers Union. The effect of these developments is to increase the number and variety of agencies dealing with medical care problems in the community. Finding the most beneficial method of integrating the activities of these several agencies should be a problem of major interest to medical practitioners, health administrators and the public alike.



4. **URBANIZATION OF THE POPULATION.** Increasing urbanization of the population has also changed the character of the health problems which must be dealt with today. Not only has there been urbanization of the population itself, but there has also been increasing urbanization of medical resources and medical knowledge. These trends have led to various plans designed to improve the medical and public health facilities of the rural areas, most of which seek to develop a regional pattern with the urban medical center at the hub and small hospitals affiliated with health departments on the periphery.

In urban areas, increasing concentration of the population has brought new environmental control problems in relation to waste disposal, food, and water supply, and has served to emphasize the increasing importance of housing in the health picture. These are problems which are dealt with on a community basis. On the other hand, the urbanization of medical facilities and the rise of the chronic diseases has led to an approach to the problems of specific illnesses, such as cancer and heart disease, through the individual as well as through the population in general.

### NATALITY AND MORTALITY

One cannot progress very far in an examination of the characteristics of the population and their relationship to health and disease without consideration of the course of the birth and death rates. The relationship of these vital statistics to each other is a major determining factor in the future course of the population. In addition, they provide a particular kind of measure of the health of the population. The fact that the mortality from all forms of tuberculosis has dropped from 71.1 per 100,000 population in 1930 to 33.5 in 1947 is a source of gratification to all concerned with the health of the public. On the other hand, the steadily climbing death rates from cancer and heart disease are indicative of the problems still before us.

**Source of Data.** Historically, in the United States, information concerning the occurrence of births and deaths in a population was obtained by attempting to take a census of these events just as we take a census of population. This procedure, however, proved very unsatisfactory, and today the occurrence of births and deaths in the population is obtained through a registration system. For a description of early methods of collecting the data on births and deaths, see Billings (1880).

The essence of the registration procedure is the requirement that whenever a birth or death occurs, a certificate indicating this fact must be filed with a local registrar of vital statistics within a short period of time after the occurrence of the event. In the case of a birth, a physician is responsible for seeing that the birth certificate is filed with a local registrar. In the case of a death, however, the physician is responsible only for certifying to the medical facts concerning the death, while the funeral director is responsible for the actual filing of the certificate with the local registrar. Essentially the same procedure holds for stillbirths. Figure 45-2, taken from the *Physician's Handbook on Death and Birth Registration*, Tenth Edition, shows the detailed flow of these certificates from their initiation by the physician to their final filing in the State Health Department of Vital Statistics.\*

\* Certain cities and local health departments may be permitted to file these certificates in their own offices.

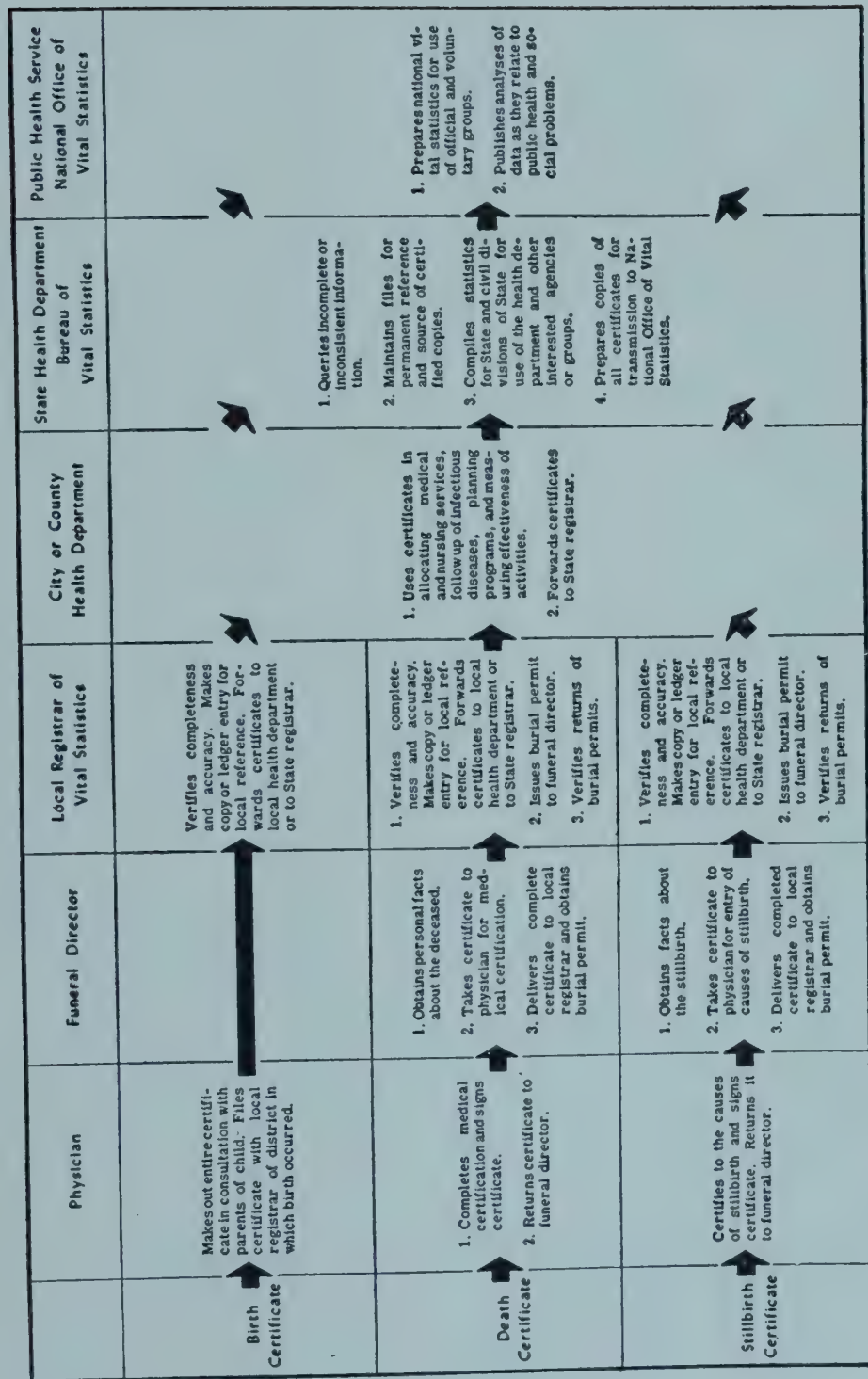


Fig. 45-2. The registration system in the United States. Flow chart of birth, death and stillbirth certificates.



**Uses of the Death and Birth Certificates.** There are two general functions served by death and birth certificates. One of these has to do with the protection of the rights of the individual. The death certificate establishes the fact and date of death for such purposes as: (a) claiming life insurance carried by the decedent; (b) claiming pensions; (c) settling estates; (d) providing information concerning age, sex or race, etc. The birth certificate is ordinarily used for such purposes as: (a) establishing the date of birth for entrance to school; (b) obtaining licenses; (c) entering military services; (d) voting; (e) proving citizenship; (f) establishing family relationships; etc.

The second major function of the certificates is statistical. The tabulation and analysis of the data present on the death certificate aid in determining the incidence of specific causes of death, in planning the control of communicable disease, in investigating the nature and occurrence of fatal accidents, in establishing the need for health programs and in measuring the effectiveness of health services. The birth certificate provides information on which health departments base plans for immunization of children, care of crippled children, evaluation of the need for health facilities and the evaluation of the effectiveness of infant care. In addition, statistics derived from birth and death records provide data for basic research and for program planning and evaluation.

**The Standard Certificates of Birth and Death.** In order to serve the purposes indicated in the above paragraph, the information on the birth and death certificates should be reasonably uniform among the several states. Without such uniformity, good national statistics and comparisons among states would be virtually impossible. Although each state has the right to use any certificate it pleases, the Federal Government has led the way toward uniformity with the development of model certificates to serve the states as a guide. Most states follow this model certificate in major respects.

The standard certificates of death, birth and stillbirth are shown in Figures 45-3, 45-4 and 45-5. The particular items which sometimes cause difficulty and the general instructions for filling them in are shown in the figures. However, certain items are of such great importance that they deserve special comment.

**THE BIRTH CERTIFICATE.** Because of the importance of the certificate in later life to prove the date and place of birth, it is very important that the name of the child and the parents be clearly written, as well as the date of birth of the child.

**THE DEATH CERTIFICATE.** The physician is responsible for filling out the medical part of the death certificate, whereas the funeral director is responsible for the personal particulars on the certificate. The medical information requested on the Standard Certificate of Death is based upon the recommendations of the World Health Assembly made in Geneva in July, 1948. It has been accepted by all states in this country and is being put into general use.

The most important feature of the medical certification is its emphasis on *the underlying cause as determined by the physician*. Tabulations made from the information supplied by the physician will reflect the frequency with which these underlying causes occur. Clearly the data in these tabulations can be only as accurate as the original certification by the physician. In the final analysis, it is the physician who determines the reliability of the information available on the causes

This is a permanent document. Type or use permanent black ink. Do not use ball-type pen.

THE FUNERAL DIRECTOR IS TO COMPLETE ITEMS 1-3, 5-17, 24, 25.

To be filled in by Vital Statistics Office.

Differentiate between urban and rural areas (i.e., within or outside city or town limits).

Use such terms as White, Negro, Indian, etc.

Complete both 10(a) and 10(b) for all persons 14 years and over, even though disabled, retired, unemployed or institutionalized.

In 10(a) give occupation followed during most of working life. Use specific terms, such as welder, farm laborer, carpenter, etc.

In 10(b) give business or industry in which occupation named in 10(a) was followed. Use specific terms, such as coal mine, cotton mill, automobile factory, farm, etc. Do not use company or organization names.

THE PHYSICIAN, MEDICAL EXAMINER, OR CORONER IS TO COMPLETE ITEMS 4, 18-23.

In part I, give the sequence of events that led to death, specifying last the underlying cause which initiated the train of events. Do not report symptoms or mode of dying.

In part II, report other important diseases or conditions, if any, that contributed to the death but were not related to the causes given in part I above.

Complete items 21(a) - 21(f) if death was due to violence or external causes.

Form 45-3 (1949 Revision of Standard Certificate) CERTIFICATE OF DEATH

Form 45-3 (Revised, Budget Bureau No. 45-375)

STATE OF Michigan STATE FILE NO.

1. PLACE OF DEATH a. COUNTY Crawford b. CITY OF RURAL-GRAYLING TWP. c. CITY (if outside corporate limits, give RURAL, and give township) d. TOWN Rural e. BEAVER CREEK TWP. f. FULL ADDRESS (if not in hospital or institution, give street, city, county, and state) g. STREET ADDRESS RR 1 Roscommon

2. USUAL RESIDENCE a. STATE Michigan b. COUNTY Crawford c. CITY (if outside corporate limits, give RURAL, and give township) d. TOWN Rural e. BEAVER CREEK TWP. f. FULL ADDRESS (if not in hospital or institution, give street, city, county, and state) g. STREET ADDRESS RR 1 Roscommon

3. NAME OF DECEASED (Last, first, middle) James Smith

4. DATE OF DEATH (Month, Day, Year) June 21, 1949

5. SEX Male

6. COLOR OR RACE Negro

7. MARRIED NEVER MARRIED

8. DATE OF BIRTH (Month, Day, Year) April 10, 1912

9. AGE (in years, if under 1 year, give weeks and days) 37

10. USUAL OCCUPATION (Give kind of work done during most of working life, and if disabled, the mode of living, such as retired, invalid, etc.) Retail coal

11. BIRTHPLACE (State or foreign country) South Carolina

12. CITIZEN OF WHAT COUNTRY? U.S.A.

13. FATHER'S NAME James Smith

14. MOTHER'S MAIDEN NAME Maude Richardson

15. WAS DECEASED EVER IN U.S. ARMED FORCES? YES

16. SOCIAL SECURITY NO. 232-02-5678

17. INFORMANT Mary Alice Smith

18. CAUSE OF DEATH (a) DISEASE OR CONDITION DIRECTLY LEADING TO DEATH (a) Tuberculous meningitis (b) MEDICAL CERTIFICATION Pulmonary tuberculosis (c) DUE TO (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z) (aa) (ab) (ac) (ad) (ae) (af) (ag) (ah) (ai) (aj) (ak) (al) (am) (an) (ao) (ap) (aq) (ar) (as) (at) (au) (av) (aw) (ax) (ay) (az) (ba) (bb) (bc) (bd) (be) (bf) (bg) (bh) (bi) (bj) (bk) (bl) (bm) (bn) (bo) (bp) (bq) (br) (bs) (bt) (bu) (bv) (bw) (bx) (by) (bz) (ca) (cb) (cc) (cd) (ce) (cf) (cg) (ch) (ci) (cj) (ck) (cl) (cm) (cn) (co) (cp) (cq) (cr) (cs) (ct) (cu) (cv) (cw) (cx) (cy) (cz) (da) (db) (dc) (dd) (de) (df) (dg) (dh) (di) (dj) (dk) (dl) (dm) (dn) (do) (dp) (dq) (dr) (ds) (dt) (du) (dv) (dw) (dx) (dy) (dz) (ea) (eb) (ec) (ed) (ee) (ef) (eg) (eh) (ei) (ej) (ek) (el) (em) (en) (eo) (ep) (eq) (er) (es) (et) (eu) (ev) (ew) (ex) (ey) (ez) (fa) (fb) (fc) (fd) (fe) (ff) (fg) (fh) (fi) (fj) (fk) (fl) (fm) (fn) (fo) (fp) (fq) (fr) (fs) (ft) (fu) (fv) (fw) (fx) (fy) (fz) (ga) (gb) (gc) (gd) (ge) (gf) (gg) (gh) (gi) (gj) (gk) (gl) (gm) (gn) (go) (gp) (gq) (gr) (gs) (gt) (gu) (gv) (gw) (gx) (gy) (gz) (ha) (hb) (hc) (hd) (he) (hf) (hg) (hh) (hi) (hj) (hk) (hl) (hm) (hn) (ho) (hp) (hq) (hr) (hs) (ht) (hu) (hv) (hw) (hx) (hy) (hz) (ia) (ib) (ic) (id) (ie) (if) (ig) (ih) (ii) (ij) (ik) (il) (im) (in) (io) (ip) (iq) (ir) (is) (it) (iu) (iv) (iw) (ix) (iy) (iz) (ja) (jb) (jc) (jd) (je) (jf) (jg) (jh) (ji) (jj) (jk) (jl) (jm) (jn) (jo) (jp) (jq) (jr) (js) (jt) (ju) (jv) (jw) (jx) (jy) (jz) (ka) (kb) (kc) (kd) (ke) (kf) (kg) (kh) (ki) (kj) (kk) (kl) (km) (kn) (ko) (kp) (kq) (kr) (ks) (kt) (ku) (kv) (kw) (kx) (ky) (kz) (la) (lb) (lc) (ld) (le) (lf) (lg) (lh) (li) (lj) (lk) (ll) (lm) (ln) (lo) (lp) (lq) (lr) (ls) (lt) (lu) (lv) (lw) (lx) (ly) (lz) (ma) (mb) (mc) (md) (me) (mf) (mg) (mh) (mi) (mj) (mk) (ml) (mm) (mn) (mo) (mp) (mq) (mr) (ms) (mt) (mu) (mv) (mw) (mx) (my) (mz) (na) (nb) (nc) (nd) (ne) (nf) (ng) (nh) (ni) (nj) (nk) (nl) (nm) (nn) (no) (np) (nq) (nr) (ns) (nt) (nu) (nv) (nw) (nx) (ny) (nz) (oa) (ob) (oc) (od) (oe) (of) (og) (oh) (oi) (oj) (ok) (ol) (om) (on) (oo) (op) (oq) (or) (os) (ot) (ou) (ov) (ow) (ox) (oy) (oz) (pa) (pb) (pc) (pd) (pe) (pf) (pg) (ph) (pi) (pj) (pk) (pl) (pm) (pn) (po) (pp) (pq) (pr) (ps) (pt) (pu) (pv) (pw) (px) (py) (pz) (qa) (qb) (qc) (qd) (qe) (qf) (qg) (qh) (qi) (qj) (qk) (ql) (qm) (qn) (qo) (qp) (qq) (qr) (qs) (qt) (qu) (qv) (qw) (qx) (qy) (qz) (ra) (rb) (rc) (rd) (re) (rf) (rg) (rh) (ri) (rj) (rk) (rl) (rm) (rn) (ro) (rp) (rq) (rr) (rs) (rt) (ru) (rv) (rw) (rx) (ry) (rz) (sa) (sb) (sc) (sd) (se) (sf) (sg) (sh) (si) (sj) (sk) (sl) (sm) (sn) (so) (sp) (sq) (sr) (ss) (st) (su) (sv) (sw) (sx) (sy) (sz) (ta) (tb) (tc) (td) (te) (tf) (tg) (th) (ti) (tj) (tk) (tl) (tm) (tn) (to) (tp) (tq) (tr) (ts) (tt) (tu) (tv) (tw) (tx) (ty) (tz) (ua) (ub) (uc) (ud) (ue) (uf) (ug) (uh) (ui) (uj) (uk) (ul) (um) (un) (uo) (up) (uq) (ur) (us) (ut) (uu) (uv) (uw) (ux) (uy) (uz) (va) (vb) (vc) (vd) (ve) (vf) (vg) (vh) (vi) (vj) (vk) (vl) (vm) (vn) (vo) (vp) (vq) (vr) (vs) (vt) (vu) (vv) (vw) (vx) (vy) (vz) (wa) (wb) (wc) (wd) (we) (wf) (wg) (wh) (wi) (wj) (wk) (wl) (wm) (wn) (wo) (wp) (wq) (wr) (ws) (wt) (wu) (wv) (ww) (wx) (wy) (wz) (xa) (xb) (xc) (xd) (xe) (xf) (xg) (xh) (xi) (xj) (xk) (xl) (xm) (xn) (xo) (xp) (xq) (xr) (xs) (xt) (xu) (xv) (xw) (xx) (xy) (xz) (ya) (yb) (yc) (yd) (ye) (yf) (yg) (yh) (yi) (yj) (yk) (yl) (ym) (yn) (yo) (yp) (yq) (yr) (ys) (yt) (yu) (yv) (yw) (yx) (yy) (yz) (za) (zb) (zc) (zd) (ze) (zf) (zg) (zh) (zi) (zj) (zk) (zl) (zm) (zn) (zo) (zp) (zq) (zr) (zs) (zt) (zu) (zv) (zw) (zx) (zy) (zz)

19. DATE OF OPERATION

20. AUTOPSY? YES ☐ NO ☒

21. PLACE OF INJURY (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z) (aa) (ab) (ac) (ad) (ae) (af) (ag) (ah) (ai) (aj) (ak) (al) (am) (an) (ao) (ap) (aq) (ar) (as) (at) (au) (av) (aw) (ax) (ay) (az) (ba) (bb) (bc) (bd) (be) (bf) (bg) (bh) (bi) (bj) (bk) (bl) (bm) (bn) (bo) (bp) (bq) (br) (bs) (bt) (bu) (bv) (bw) (bx) (by) (bz) (ca) (cb) (cc) (cd) (ce) (cf) (cg) (ch) (ci) (cj) (ck) (cl) (cm) (cn) (co) (cp) (cq) (cr) (cs) (ct) (cu) (cv) (cw) (cx) (cy) (cz) (da) (db) (dc) (dd) (de) (df) (dg) (dh) (di) (dj) (dk) (dl) (dm) (dn) (do) (dp) (dq) (dr) (ds) (dt) (du) (dv) (dw) (dx) (dy) (dz) (ea) (eb) (ec) (ed) (ee) (ef) (eg) (eh) (ei) (ej) (ek) (el) (em) (en) (eo) (ep) (eq) (er) (es) (et) (eu) (ev) (ew) (ex) (ey) (ez) (fa) (fb) (fc) (fd) (fe) (ff) (fg) (fh) (fi) (fj) (fk) (fl) (fm) (fn) (fo) (fp) (fq) (fr) (fs) (ft) (fu) (fv) (fw) (fx) (fy) (fz) (ga) (gb) (gc) (gd) (ge) (gf) (gg) (gh) (gi) (gj) (gk) (gl) (gm) (gn) (go) (gp) (gq) (gr) (gs) (gt) (gu) (gv) (gw) (gx) (gy) (gz) (ha) (hb) (hc) (hd) (he) (hf) (hg) (hh) (hi) (hj) (hk) (hl) (hm) (hn) (ho) (hp) (hq) (hr) (hs) (ht) (hu) (hv) (hw) (hx) (hy) (hz) (ia) (ib) (ic) (id) (ie) (if) (ig) (ih) (ii) (ij) (ik) (il) (im) (in) (io) (ip) (iq) (ir) (is) (it) (iu) (iv) (iw) (ix) (iy) (iz) (ja) (jb) (jc) (jd) (je) (jf) (jg) (jh) (ji) (jj) (jk) (jl) (jm) (jn) (jo) (jp) (jq) (jr) (js) (jt) (ju) (jv) (jw) (jx) (jy) (jz) (ka) (kb) (kc) (kd) (ke) (kf) (kg) (kh) (ki) (kj) (kk) (kl) (km) (kn) (ko) (kp) (kq) (kr) (ks) (kt) (ku) (kv) (kw) (kx) (ky) (kz) (la) (lb) (lc) (ld) (le) (lf) (lg) (lh) (li) (lj) (lk) (ll) (lm) (ln) (lo) (lp) (lq) (lr) (ls) (lt) (lu) (lv) (lw) (lx) (ly) (lz) (ma) (mb) (mc) (md) (me) (mf) (mg) (mh) (mi) (mj) (mk) (ml) (mm) (mn) (mo) (mp) (mq) (mr) (ms) (mt) (mu) (mv) (mw) (mx) (my) (mz) (na) (nb) (nc) (nd) (ne) (nf) (ng) (nh) (ni) (nj) (nk) (nl) (nm) (nn) (no) (np) (nq) (nr) (ns) (nt) (nu) (nv) (nw) (nx) (ny) (nz) (oa) (ob) (oc) (od) (oe) (of) (og) (oh) (oi) (oj) (ok) (ol) (om) (on) (oo) (op) (oq) (or) (os) (ot) (ou) (ov) (ow) (ox) (oy) (oz) (pa) (pb) (pc) (pd) (pe) (pf) (pg) (ph) (pi) (pj) (pk) (pl) (pm) (pn) (po) (pp) (pq) (pr) (ps) (pt) (pu) (pv) (pw) (px) (py) (pz) (qa) (qb) (qc) (qd) (qe) (qf) (qg) (qh) (qi) (qj) (qk) (ql) (qm) (qn) (qo) (qp) (qq) (qr) (qs) (qt) (qu) (qv) (qw) (qx) (qy) (qz) (ra) (rb) (rc) (rd) (re) (rf) (rg) (rh) (ri) (rj) (rk) (rl) (rm) (rn) (ro) (rp) (rq) (rr) (rs) (rt) (ru) (rv) (rw) (rx) (ry) (rz) (sa) (sb) (sc) (sd) (se) (sf) (sg) (sh) (si) (sj) (sk) (sl) (sm) (sn) (so) (sp) (sq) (sr) (ss) (st) (su) (sv) (sw) (sx) (sy) (sz) (ta) (tb) (tc) (td) (te) (tf) (tg) (th) (ti) (tj) (tk) (tl) (tm) (tn) (to) (tp) (tq) (tr) (ts) (tt) (tu) (tv) (tw) (tx) (ty) (tz) (ua) (ub) (uc) (ud) (ue) (uf) (ug) (uh) (ui) (uj) (uk) (ul) (um) (un) (uo) (up) (uq) (ur) (us) (ut) (uu) (uv) (uw) (ux) (uy) (uz) (va) (vb) (vc) (vd) (ve) (vf) (vg) (vh) (vi) (vj) (vk) (vl) (vm) (vn) (vo) (vp) (vq) (vr) (vs) (vt) (vu) (vv) (vw) (vx) (vy) (vz) (wa) (wb) (wc) (wd) (we) (wf) (wg) (wh) (wi) (wj) (wk) (wl) (wm) (wn) (wo) (wp) (wq) (wr) (ws) (wt) (wu) (wv) (ww) (wx) (wy) (wz) (xa) (xb) (xc) (xd) (xe) (xf) (xg) (xh) (xi) (xj) (xk) (xl) (xm) (xn) (xo) (xp) (xq) (xr) (xs) (xt) (xu) (xv) (xw) (xx) (xy) (xz) (ya) (yb) (yc) (yd) (ye) (yf) (yg) (yh) (yi) (yj) (yk) (yl) (ym) (yn) (yo) (yp) (yq) (yr) (ys) (yt) (yu) (yv) (yw) (yx) (yy) (yz) (za) (zb) (zc) (zd) (ze) (zf) (zg) (zh) (zi) (zj) (zk) (zl) (zm) (zn) (zo) (zp) (zq) (zr) (zs) (zt) (zu) (zv) (zw) (zx) (zy) (zz)

22. I hereby certify that I attended the deceased from February 4, 1949, to June 21, 1949, that I last saw the deceased alive on June 21, 1949, and that death occurred at 4:25 P.M. from the causes and on the date stated above.

23. SIGNATURE Walter A. Blovin, M.D.

24. DATE June 24, 1949

25. NAME OF CEMETERY OR CREMATORY Grayling, Michigan

26. LOCATION (City, town, or county) Grayling, Michigan

27. FUNERAL DIRECTOR (Name and address) Van Buren Co., Grayling, Michigan

28. REGISTRAR'S SIGNATURE (Name and address) John J. Jones, Grayling, Michigan

29. DATE OF DEATH June 23, 1949

30. PLACE OF DEATH (City, town, or county) Grayling, Michigan

31. PLACE OF BIRTH (City, town, or county) South Carolina

32. PLACE OF DEATH (City, town, or county) Grayling, Michigan

33. PLACE OF BIRTH (City, town, or county) South Carolina

34. PLACE OF DEATH (City, town, or county) Grayling, Michigan

35. PLACE OF BIRTH (City, town, or county) South Carolina

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99. PLACE OF BIRTH (City, town, or county) South Carolina

100. PLACE OF DEATH (City, town, or county) Grayling, Michigan

Fig. 45-3. The standard certificate of death.



This is a permanent document. Type or use permanent black ink. Do not use ball-type pen.

PHS-700 (VS)  
FEDERAL AGENCY  
PUBLIC HEALTH SERVICE

(1949 Revision of Standard Certificate)  
**CERTIFICATE OF LIVE BIRTH**

Form approved  
Budget Bureau No. 66-R774

STATE OF Missouri

1 PLACE OF BIRTH  
a. COUNTY Dent  
b. CITY (If outside corporate limits, write RURAL and give township and town) Salem City  
c. FULL NAME OF HOSPITAL OR INSTITUTION Grandview Hospital

2 USUAL RESIDENCE OF MOTHER (Write date, residence type)  
a. STATE Missouri  
b. CITY (If outside corporate limits, write RURAL and give township and town) Rural - Spring Creek  
c. STREET ADDRESS Five Corners (If rural, give location)

3 CHILD'S NAME  
(Type of birth)  
a. (First) George  
b. (Middle) Henry  
c. (Last) Coe

4a. SEX Male  
b. SINGLE ☒ MARRIED ☐ TRIPLET ☐  
c. IF TWIN OR TRIPLET (How should born) 1ST ☐ 2ND ☐ 3RD ☐

5 DATE (Month) (Day) (Year)  
BIRTH March 8 1949

6 COLOR OR RACE White

7 FULL NAME  
a. (First) Robert  
b. (Middle) Thomas  
c. (Last) Coe

8 AGE (as time of this birth) 29 YEARS

9 BIRTHPLACE (Name of foreign country)  
Illinois

10 USUAL OCCUPATION  
Farm laborer

11a. KIND OF BUSINESS OR INDUSTRY  
Farm

12 FULL MAIDEN NAME a. (First) Sarah Jane b. (Middle) Coe c. (Last) Mathews

13 AGE (as time of this birth) 26 YEARS

14 BIRTHPLACE (Name of foreign country)  
Missouri

15 CHILDREN PREVIOUSLY BORN TO THIS MOTHER (Do not include stillborns)  
a. How many OTHER CHILDREN 1  
b. How many BORN ALIVE BUT ARE DEAD 0  
c. How many BORN ALIVE BUT ARE STILLBORN 0

16 INFORMANT Sarah Jane Coe

17a. SIGNATURE William B. Garfield M.D.  
b. ADDRESS 205 Elm St., Salem City, Missouri

18 DATE REC'D BY LOCAL HEALTH DEPT. March 10, 1949

19 DATE OF BIRTH March 9, 1949

20 REGISTRAR'S SIGNATURE Bryan S. Franken

21 DATE ON WHICH GIVEN NAME ADDED BY (If later):

22a. LENGTH OF PREGNANCY 38 WEEKS  
b. WEIGHT AT BIRTH 7 LBS 2 OZS  
c. LEGITIMATE ☒ YES ☐ NO

FOR MEDICAL AND HEALTH USE ONLY  
(This section MUST be filled out)

(SPACE FOR ADDITION OF MEDICAL AND HEALTH ITEMS BY INDIVIDUAL STATES)

To be filled in by Vital Statistics Office.

Differentiate between urban and rural areas (i.e., within or outside city or town limits).

If rural, give name of neighborhood, locality, or section (e.g., Salem, Five Corners, Three Oaks, etc.).

Use such terms as White, Negro, Indian, etc.

Give business or industry in which occupation named in item 11(a) was followed. Use specific terms, such as coal mine, cotton mill, automobile factory, farm, etc. Do not use company or organization names.

Indicate occupation followed during most of working life. Use specific terms, such as welder, farm laborer, carpenter, etc.

Fig. 45-4. The standard certificate of live birth.

This is a permanent document. Type or use permanent black ink. Do not use ball-type pen.

THE FUNERAL DIRECTOR IS TO COMPLETE ITEMS 1-5, 7-17, 25, 26.

Differentiate between urban and rural areas (i.e., within or outside city or town limits).

In cases of plural births, separate certificates must be prepared for each liveborn or stillborn child.

Use such terms as White, Negro, Indian, etc.

For 11(a) give occupation followed during most of working life. Use specific terms, such as welder, farm laborer, carpenter, etc.

For 11(b) give business or industry in which occupation named in item 11(a) was followed. Use specific terms, such as coal mine, cotton mill, automobile factory, farm, etc. Do not use company or organization names.

An entry should be made for each item, (a), (b), and (c). Enter "0" when this is the proper answer.

THE PHYSICIAN IS TO COMPLETE ITEMS 6, 18-23.

Report fetal causes of stillbirth and also maternal causes, if any. Give specific type of congenital malformation or disease of fetus, and of disease or condition of the mother.

PHS-757(V8)  
FEDERAL SECURITY AGENCY  
PUBLIC HEALTH SERVICE

(1949 Revision of Standard Certificate)  
**CERTIFICATE OF STILLBIRTH**

Form approved,  
Bureau No. 46-1372

STATE OF California

STATE FILE NO.

1. PLACE OF STILLBIRTH  
a. COUNTY Los Angeles  
b. CITY (If outside corporate limits, give rural and give township) Los Angeles  
c. CITY (If inside corporate limits, write RURAL and give township) Los Angeles  
d. STREET ADDRESS (If rural, give location) Cedar Hill Hospital 1045 East Garfield St.

2. USUAL RESIDENCE OF MOTHER (When time another birth)  
a. STATE California b. COUNTY Los Angeles  
c. CITY (If inside corporate limits, write RURAL and give township) Los Angeles  
d. STREET ADDRESS (If rural, give location) 1045 East Garfield St.

3. CHILD'S NAME  
(Type or Print) Baby Boy Simmons

4. SEX Male  
5. IF TWIN OR TRIPLET (Type and birth order) 1ST 2ND 3RD 4TH 5TH 6TH 7TH 8TH 9TH 10TH 11TH 12TH 13TH 14TH 15TH 16TH 17TH 18TH 19TH 20TH 21ST 22ND 23RD 24TH 25TH 26TH 27TH 28TH 29TH 30TH 31ST 32ND 33RD 34TH 35TH 36TH 37TH 38TH 39TH 40TH 41ST 42ND 43RD 44TH 45TH 46TH 47TH 48TH 49TH 50TH 51ST 52ND 53RD 54TH 55TH 56TH 57TH 58TH 59TH 60TH 61ST 62ND 63RD 64TH 65TH 66TH 67TH 68TH 69TH 70TH 71ST 72ND 73RD 74TH 75TH 76TH 77TH 78TH 79TH 80TH 81ST 82ND 83RD 84TH 85TH 86TH 87TH 88TH 89TH 90TH 91ST 92ND 93RD 94TH 95TH 96TH 97TH 98TH 99TH 100TH 101ST 102ND 103RD 104TH 105TH 106TH 107TH 108TH 109TH 110TH 111TH 112TH 113TH 114TH 115TH 116TH 117TH 118TH 119TH 120TH 121ST 122ND 123RD 124TH 125TH 126TH 127TH 128TH 129TH 130TH 131ST 132ND 133RD 134TH 135TH 136TH 137TH 138TH 139TH 140TH 141ST 142ND 143RD 144TH 145TH 146TH 147TH 148TH 149TH 150TH 151ST 152ND 153RD 154TH 155TH 156TH 157TH 158TH 159TH 160TH 161ST 162ND 163RD 164TH 165TH 166TH 167TH 168TH 169TH 170TH 171ST 172ND 173RD 174TH 175TH 176TH 177TH 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of death and the success of efforts to control mortality as measured by the vital statistics.

**THE STILLBIRTH CERTIFICATE.** In order to reduce fetal and maternal losses, it is essential that medical and health agencies have data on the extent of the stillbirth problem and of the fetal and maternal conditions associated with it. As in the case of a death, the physician is responsible for the medical part of the certificate. *A stillbirth is defined as a fetus showing no evidence of life after complete birth (no action of heart, breathing, or movement of voluntary muscle) if the twentieth week of gestation has been reached.* There is still some variation among the states in the employment of this definition. The physician and nurse should inquire of the state health department what definition is followed in their state. If there is any evidence of life after complete birth, even though momentary, the birth should be registered as a live birth, and a death certificate also filed.

Detailed instructions for filling out the birth, death and stillbirth certificates may be found in the *Physician's Handbook on Death and Birth Registration*, Tenth Edition. The Handbook is available from the National Office of Vital Statistics, Washington 25, D. C.

**Factors Influencing the Reliability of Registration Data.** There are a number of factors to be considered in the interpretation of data derived from the vital statistics registration system. Among these are the accuracy of certification, the completeness of reporting, and the statistical classification of the material in the vital statistics offices.\*

1. **CERTIFICATION.** The accuracy of the statements concerning causes of death has increased with advances in medical knowledge and with the development of understanding on the part of the physician of the importance of the death certificate. Indirect evidence of this is the rising proportion through the years of certificates reporting more than one cause and the nature of the causes themselves. A smaller proportion of vague and ill-defined terms is found on death certificates today than used to be the case. However, there are still many certificates bearing such terms as "heart disease" which do not aid very much in attempting to define the present day problem of the cardiovascular diseases, since there may be so many different things giving rise to so-called "heart disease." The more accurately the cause of death is stated on the certificate, the greater will be our understanding of the factors contributing to mortality from specific causes.

2. **COMPLETENESS OF REPORTING.** Clearly if all births or deaths are not reported the resulting birth or death rate will be too small. Various tests of completeness of reporting of births have been made from time to time, the most recent large scale one reported on being that conducted by the National Office of Vital Statistics in conjunction with the 1940 Census (Grove, 1941). This study indicated that for the United States as a whole, about 92.5 per cent of the births were reported. However, there was considerable variation in various parts of the country, the lowest percentage recorded being 79.6 per cent and the highest 99.4 per cent.

In examining the trend of various vital statistics rates, one should seek an explanation for any sudden changes in the direction of the trend, since a sudden change in reporting may raise or lower the rate. In the case of the infant mortality

\* Where only one of the three types of data—mortality, natality, stillbirth—is mentioned, it is to be understood that the discussion which follows is equally pertinent to the other two types.

rate, the neonatal mortality rate and the maternal mortality rate (see page 1318, Chapter 44) changes in completeness of reporting may affect either numerator or denominator, a rise in the former increasing the rate, and in the latter decreasing it. A method of studying the effect of incompleteness of reporting on the birth rate, the stillbirth rate, and the infant mortality rate through the use of current records on file in local health departments was reported by Peterson (1940).

3. **CLASSIFICATION.** The classification procedure employed in tabulating the large masses of vital statistics data may have a very marked effect upon the various vital statistics rates (see page 1313, Chapter 44). This is well illustrated by the classification of causes of death. The importance and general applicability of this classification warrant a discussion of its development before presenting an example of how its use may affect the death rates.

The thousands of different medical terms—good, bad and indifferent—used to describe diseases and their manifestations must be grouped in some way if “generalizations are to be made about the health conditions in various localities, the efficacy of public health work, and the progress of therapeutic medicine” (Linder and Grove, 1943). The recognition that such a grouping is needed is not new. The foundations for the present grouping, known as the International Statistical Classification of Diseases, Injuries and Causes of Death, were begun in 1853 by William Farr and Marc D’Espine. The present classification is the sixth revision of the original International List adopted in 1893. Former lists dealt only with mortality, but the present classification includes morbidity as well.

“There are many approaches to the classification of disease. The anatomist, for example, may desire a classification based on the part of the body affected. The pathologist, on the other hand, is primarily interested in the nature of the disease process. The clinician must consider disease from these two angles, but needs further knowledge of etiology. In other words, there are many axes of classification and the particular axis selected will be determined by the interests of the investigator. A statistical classification of disease and injury will depend, therefore, upon the use to be made of the statistics to be compiled” (World Health Organization, 1948). In keeping with this principle, the 1948 revision of the International Classification groups the various diseases and morbid conditions into 612 categories plus certain additional categories for the classification of injuries by external cause and by nature of the lesion. These categories are in turn grouped into 17 main sections, such as Infective and Parasitic Diseases, Neoplasms, etc.

This classification process may affect the death rate for a specific cause in two general ways:

1. By the assignment of the certificate to a particular category of the International Classification when more than one cause of death is listed. The method \* by which this is done seeks to give priority to the primary cause of death indicated by the physician, but at times there may be exceptions. For instance, a certificate with bronchitis and typhoid fever as the causes of death, stated in that order, would be assigned to typhoid fever and would not appear in the death rate for diseases of the respiratory system.

2. By what is included under a given title. For instance, tuberculosis of the

\* The rules by which this is done are set forth in Volume I of the Classification (World Health Organization, 1948)



respiratory system is classified with the infective and parasitic diseases rather than with diseases of the respiratory system. The decision to classify tuberculosis this way is only taken after consultation with tuberculosis experts, the medical profession in general, pathologists and others concerned with the problem. The question of changes in what is included in each category is particularly troublesome when the decennial revisions of the Classification are made to bring it in line with the advances in knowledge during the previous decade. Any changes which are made will affect the comparability of data over a period of time which includes the revision date. Studies of the effect of the changes made in the Sixth Revision as compared with the Fifth Revision of the International Classification have been published by Erhardt and Weiner (1950) and by Marks (1949).

There are other classification problems which may affect the comparability of vital statistics data, such as the classification by age, race and sex, the classification into urban and rural, the classification by residence, and others. These are discussed in detail by Linder and Grove (1943).

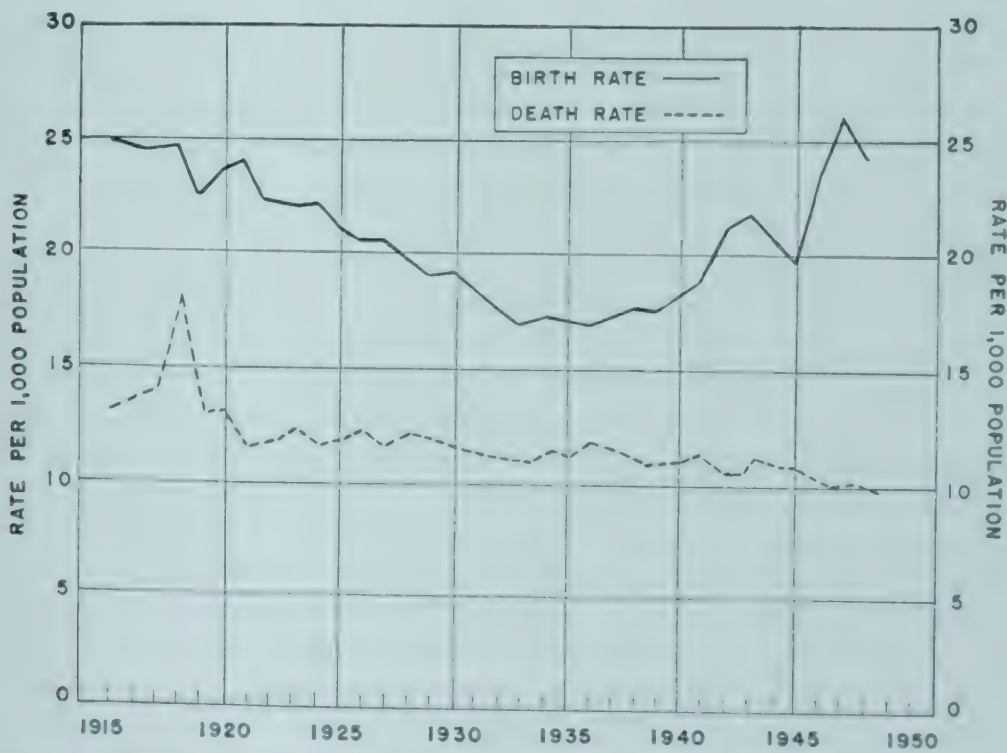


Fig. 45-6. Trend of the crude birth rate and death rate in the United States, 1915-1947.

**Natality.** The trend of the crude birth rate as revealed by analysis of the data obtained through the operation of the registration system just described is shown in Figure 45-6. Until relatively recently, the birth rate has been steadily declining until the low point in the depression year of 1933. Thereafter, there was a slow rise with improved economic conditions until the effects of the war in Europe began to be felt. The effects of the entry of the United States into the war, of the withdrawal of large numbers of young men and of the return of veterans may be traced in the curve. The 1947 figure of 25.8 per 1,000 population, the highest ever recorded, reflects the postponement of births due to the war and the earlier starting of families that might ordinarily have been begun in 1948 or later. The greatest

part of the increase has been in one- and two-child families. It seems unlikely that these high birth rates will continue indefinitely. For a detailed discussion of the effects of war on various characteristics of the population see Thompson (1948) and Whelpton (1948).

A better measure of the inherent reproductive capacity of the population than the birth rate is the net reproduction rate. This is because the current age distribution of a population may be a result of high birth rates in the past, so that differences between the birth rate and death rate at any given time may give a false impression of the capacity of a population to reproduce itself. A net reproduction rate of exactly one means that under a given schedule of mortality and fertility, a generation of newborn girls would, by the end of the reproductive period of those that survived, have given rise to sufficient births to exactly equal the numbers of the original generation. A rate of more than one indicates an increasing population and, correspondingly, a population with a rate of less than one is not reproducing at a rate sufficient to maintain itself.\* The net reproduction rate for the United States for 1905 to 1910 was 1.34. It reached a low of 0.98 in the depression period of 1931 to 1935, but rose again thereafter, and in 1945 its value was 1.11.

**FACTORS INFLUENCING BIRTH RATES.** The significance of the decline in the birth rate and its subsequent rise cannot be appraised without more detailed knowledge of the fertility rates † of different classes of the population. There are considerable differentials among the several classes. The effect of age has been mentioned several times. Fertility rates classified by color show much higher rates for the colored population (Bureau of the Census, 1943) and in general the more rural and agricultural the region, the higher the rate. Generally speaking, the higher the socio-economic status, the lower the fertility rates (Whelpton and Kiser, 1943). However, there have been some indications that the proportional contributions to natality of the higher economic groups may be increasing (Jacobson, 1944; Ciocco, 1940c). There are large variations by educational status (Whelpton and Kiser, 1943).

A number of studies (Pearl, 1939; Stix and Notestein, 1940; Beebe, 1942) have sought an explanation of these differentials in group fertility in terms of the relative prevalence of efforts to control fertility artificially. The evidence of these studies leaves little doubt that the prevalence and effectiveness of contraceptive efforts vary directly with socio-economic status. When analysis is restricted to groups practicing contraception similarly or to groups omitting it altogether, class differences in fertility rates disappear. In other words, differences in group fertility are not inherent biological differences.

The exploration of the motivational factors which lead couples to limit the size of their families has barely begun (Whelpton and Kiser, 1943). Yet, only out of such exploration will the social and psychological factors affecting fertility emerge. If, as has been suggested at times, attempts should be made to formulate a national population policy, the pros and cons can be assessed dispassionately only against a background of facts. These are largely lacking.

\* A more complete discussion of the meaning of this rate and of the method of computation may be found in Chapter 12, Dublin and others (1949).

† The fertility rate is defined as:  $\frac{\text{children under 5}}{\text{women 20-34}} \times 1,000$ .



**Mortality.** The crude death rate in 1948 was 9.9 per 1,000 estimated population. This is the lowest rate ever to be recorded for the country as a whole and represents a decline of 42 per cent from the rate for 1900, which was 17.2 per 1,000 population. The decline has been fairly uniform over this period with the exception of the peak produced by the influenza epidemic of 1918 (see Fig. 45-6). Examination of the trend of the crude rate alone does not do full justice to the dramatic advances which have been made against disease since 1900. These are more clearly revealed by an analysis of the mortality statistics by cause.

**MORTALITY BY CAUSE.** The change in the character of the leading causes of death since 1900 is apparent in Table 19-1, page 720. Particularly striking is the reduction in the death rates for tuberculosis and pneumonia, which reflects the application of advances in medicine and public health. The fact that the diseases of middle and old age are far more prominent as causes of death in 1948 than at the turn of the century is clearly seen in the table.

Table 45-2. Number of deaths in the population of the United States in 1947 from selected causes, compared with the numbers expected in that year on the basis of the mortality rates, by sex and age prevailing in 1940

Cause of Death	Deaths in 1947		Lives Saved in 1947 by Improvement in Mortality Since 1940	Lives Lost in 1947 by Increase in Recorded Mortality Since 1940
	Actual	Expected on Basis of Mortality in 1940		
All Causes	1,445,370	1,712,396	267,026	—
Pneumonia and influenza	61,836	118,670	56,834	—
Cardiovascular-renal diseases *	671,907	723,166	51,259	—
Tuberculosis—all forms	48,064	66,301	18,237	—
External causes	124,672	139,795	15,123	—
Suicide	16,538	20,879	4,341	—
Homicide	8,555	8,785	230	—
Accidents—all forms	99,579	110,131	10,552	—
Diarrhea and enteritis	8,069	20,904	12,835	—
Principal communicable diseases of childhood	3,332	8,208	4,876	—
Measles	472	966	494	—
Scarlet fever	107	779	672	—
Whooping Cough	1,954	4,671	2,717	—
Diphtheria	799	1,792	993	—
Diabetes mellitus	37,515	41,254	3,739	—
Typhoid and paratyphoid fever	325	1,562	1,237	—
Cancer	189,811	184,872	—	4,939
All other causes	299,839	407,664	107,825	—

From Statistical Bulletin of the Metropolitan Life Insurance Company, Vol. 30, No. 8, May, 1948, (reprinted with permission.)

\* Includes intracranial lesions of vascular origin, diseases of the heart, and nephritis (all forms).

That considerable progress is still being achieved all along the disease front is brought out by the data in Table 45-2. Cancer was the only cause of death in which more lives were lost in 1947 than would have been expected in relation to the 1940 mortality. As is pointed out in the article from which the data are taken (Metropolitan Life Insurance Co., 1949), this increase is relatively small. "The extraordinary progress in reducing the death toll in the past few years, all the more remarkable because it was achieved during a period of war and postwar adjustment, is a tribute to American medical practice and public health administration."

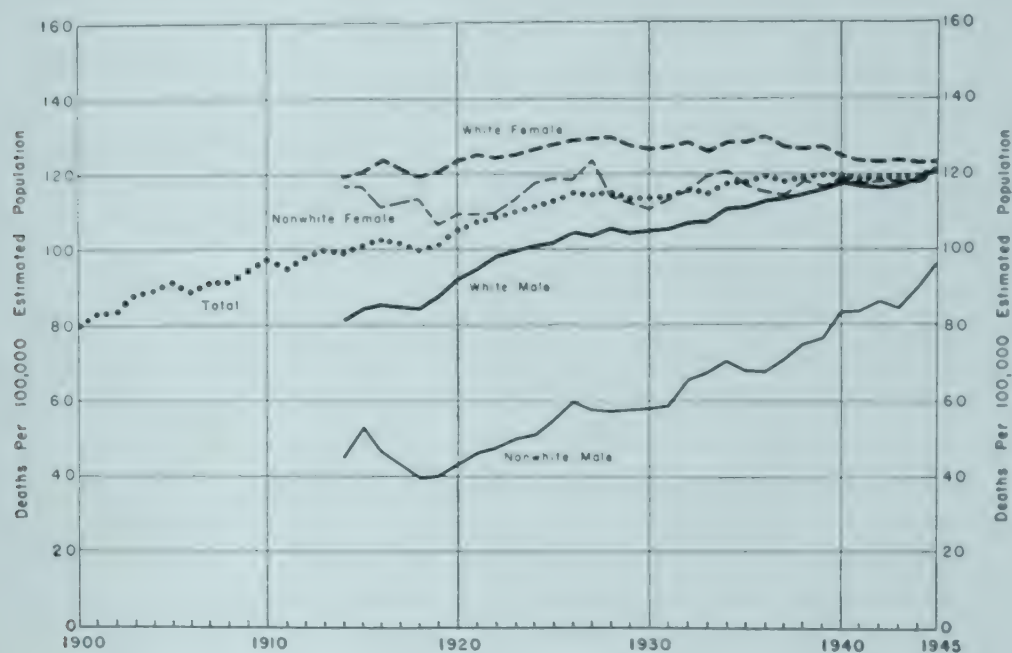
One effect of the continued decline in the mortality from the infectious and filth-borne diseases is to increase the proportion of deaths attributed to relatively few causes. In 1948, for example, nearly 50 per cent of the deaths were accounted for by the three categories of heart disease, arteriosclerosis, and cancer. The increase in the rates from cardiovascular diseases has been considered in detail in a series of Statistical Studies of Heart Diseases (1948). In the second paper in the series, Woolsey and Moriyama summarize the factors contributing to the apparently increasing death rate from this cause. They state that "Since 1930, when the registration area was virtually complete, the mortality assigned to heart disease has definitely increased for every age group over 45 years of age and has remained the same or declined in all the younger age groups. At ages over 45 years, however, there has also been a compensating decrease in the mortality from a certain group of causes of death known to be closely associated with heart disease, such as intracranial lesions of vascular origin, chronic nephritis, arteriosclerosis, and high blood pressure."

With respect to the increase in the crude death rate from cancer between 1900 and 1945 an analysis of the vital statistics data made by the National Office of Vital Statistics (1949) has the following to say: "The rapid increase in the crude death rate since 1900 is due in large part to the increase of elderly persons in the population. Although the crude death rate for cancer nearly doubled for 1945, this increase is reduced to 52 per cent after allowance is made for the aging of the population. Moreover, the increase occurred almost entirely during the first 35 years after the organization of the death registration area in 1900. Since 1935, the age-adjusted death rate has shown no appreciable change either upward or downward." This situation is shown graphically in Figure 45-7 along with the trends by race and sex. The graph also demonstrates that although the death rate from cancer among females has declined slightly in recent years, that for males has increased, although it is slackening in pace. It would also appear that there is a great deal of difference in the death rates from cancer by race, but the excess mortality of white males "is fictitious and arises from inaccuracies in recording" (National Office of Vital Statistics).

We shall not attempt a discussion of the other leading causes of death here. A detailed analysis of the trend in the mortality from accidents may be found in a report of the National Office of Vital Statistics (1949). The point may be made here, however, that the prevention of accidents is largely a matter of education and in recent years evidence has accumulated that there is an accident-prone individual toward whom efforts to reduce the toll might be directed (Farmer and Chambers, 1939; Greenwood and Woods, 1919).



For a discussion of the mortality from diabetes the reader is referred to I. M. Moriyama (1948) and to Dublin and others (1949). The latter reference also contains an extended discussion of the contribution of medical science to the reduction of mortality from specific causes.



From Federal Security Agency, Public Health Service.

Fig. 45-7. Age-adjusted cancer death rates by race and sex: death-registration states, 1900-1945.

**INFANT AND MATERNAL MORTALITY.** These two classes of mortality have been discussed in detail in Section 3, Chapter 14. It is pertinent here, however, to mention the studies of Gardiner and Yerushalmy (1939) and of Yerushalmy and others (1940a, 1940b, 1941) because of the manner in which they demonstrate the knowledge which may be gained through a study of the material on birth and death certificates. These authors point out that "maternal deaths have rarely been studied in conjunction with all the births from which they arise" and that "the distribution of maternal deaths according to the factors under investigation, when a similar distribution for the surviving mothers is not known, does not afford a measure of the risk of death associated with these factors." Only a few of their conclusions will be mentioned here as an indication of the kind of information which is available:

1. There is a strong association between death of mother and loss of offspring.
2. Rates of loss of both mother and infant were about twice as high in the group with a history of previous loss as in the group with no previous loss, and the previous losses were found to be more strongly related to loss of offspring than to loss of mother in the current pregnancy. The suggestion was made that the father may also play an important part in these cases of repeated losses in the family.

The significance of such observations for the reduction of maternal and infant mortality lies in the fact that they suggest that the increased mortality of infants born to mothers who have a history of previous loss "is due, at least in part, to constitutional and biological factors in the parents." In this connection the reader

should note that the observations were made prior to the discovery of the Rh factor. From the administrative standpoint they indicate that those in charge of maternal and child health programs may, at times, find it useful to make the program selective for those with the greatest probability of loss.

**INFLUENCE OF AGE, SEX AND RACE ON MORTALITY.** The variation in mortality by age, sex, and race may be seen in Figure 45-8. The high rate in infancy is not

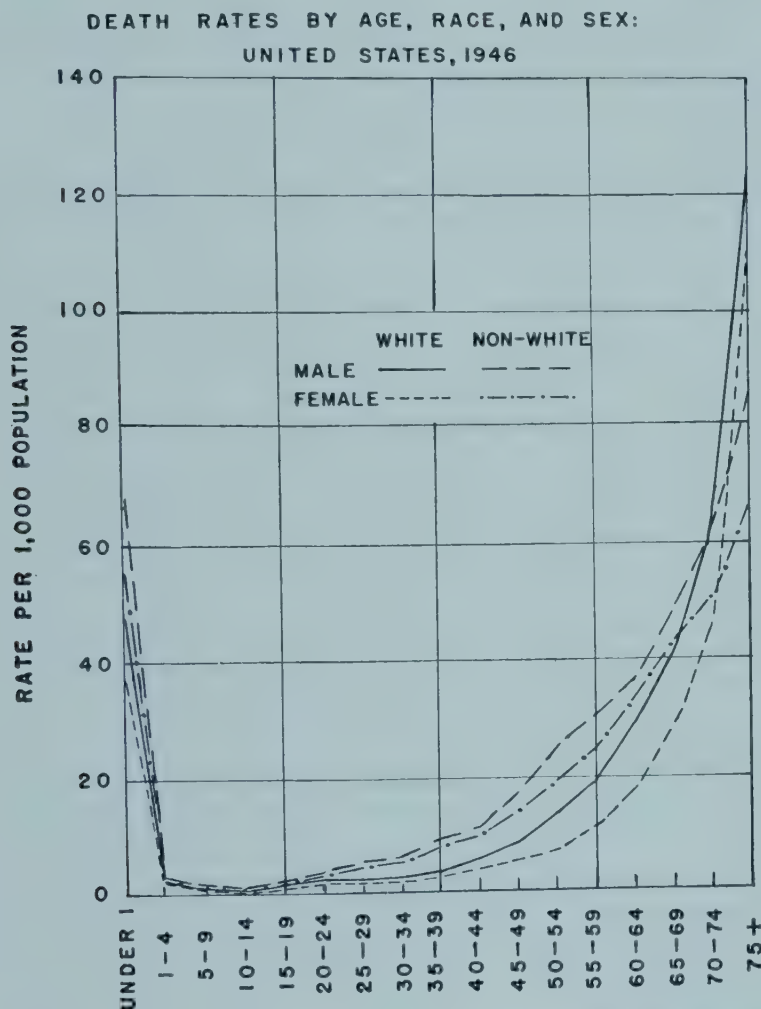


Fig. 45-8. Death rates by age, race, and sex: United States, 1946.

equalled again until about 70 years of age and the lowest point of the curve is at about 11 years of age. Table 45-3 also shows that since 1900 the mortality at every age has declined, particularly in the early years of life. The rate for the nonwhite group is higher at every age than that for the white population both for males and females. The female mortality is less than that for the male at every age, but the excess mortality of the male over the female is greater in the white population than in the nonwhite group.

Many investigators have sought explanations for the differentials in mortality by sex and race. The weight of the evidence is in favor of a biological explanation of the sex differences (Ciocco, 1940b) rather than that they are the result of different kinds of environmental exposures. The explanation for the differential mor-



Table 45-3. Death rates per 1,000 population by age groups and percentage reduction, for the death registration states: 1900 and 1947

Age Group	Deaths per 1,000 Population		Per Cent Reduction
	1900	1947	
Under 1 year	162.4	33.7	79.3
1-4 years	19.8	1.6	87.6
5-14 years	3.9	0.7	82.1
15-24 years	5.9	1.5	74.6
25-34 years	8.2	2.1	74.4
35-44 years	10.2	4.1	60.2
45-54 years	15.0	9.3	38.0
55-64 years	27.2	19.8	27.3
65-74 years	56.4	44.6	21.0
75-84 years	123.3}	117.1	
85 years and over	260.9{		
All Ages	17.2	11.5	33.2

From Statistical Abstract of the United States, 1949, Table 77, page 70. (Reproduced with permission.)

tality by race is not so clear because of the difficulty of keeping the influence of economic circumstances constant. The Negro mortality, however, appears to be declining somewhat more rapidly than the white mortality (Gover, 1946a and b, 1948).

**INFLUENCE OF OTHER FACTORS.** There are many other factors besides those already discussed which influence the risk of dying. Only a very brief summary will be attempted here primarily to indicate the direction which studies of mortality have taken. The reader is referred to Dublin and others (1949) and to Sydenstricker (1933) for more detailed discussion.

Students of the problem have long been interested in the relative importance of heredity and environment in relation to mortality. Studies which have been undertaken in the area of inheritance of longevity have been based on genealogical records, family history records and life insurance data. Although there are a number of difficulties in each of these approaches, the accumulated evidence seems to indicate that longevity is influenced by the hereditary make-up of an individual (Pearl and Pearl, 1934).

Several studies have been undertaken on the relationship of the mortality from certain causes among offspring to the mortality from these causes in ancestors. Tuberculosis, cancer, cardiovascular diseases and diabetes are examples of areas in which such studies have been undertaken. These studies seem to indicate that there is a greater concentration of mortality from these diseases in families than one would expect from a knowledge of the mortality in the general population.

The mortality by marital status is of interest because it suggests further lines of research. Generally speaking, the mortality of the unmarried is greater than that for the married of the same age. Widowed individuals seem to have the highest rates, divorced individuals come next followed by single individuals, and married individuals have the lowest rate. This relationship seems to be true irrespective of sex or race when all causes of death are considered. However, there are differences between the sexes when specific causes are taken into account.

In this connection the studies of Ciocco (1940a, 1941) are of interest. He

shows that "there is a high positive correlation in the length of life of husbands and wives" and that "there is . . . a tendency for husbands and wives to die from the same cause when one of the spouses died from either tuberculosis, influenza and pneumonia, heart disease or cancer." Analysis of the experience of siblings of the spouses and a comparison of observed mortality with that expected from random pairings of the population led Ciocco to infer that the association in length of life of spouses is "probably the result of factors that enter into marital selection" but that "the common immediate environment, or conditions depending upon the intimate personal contact, or both, seem to be especially important in the occurrence of mortality from tuberculosis, influenza, pneumonia, cancer and heart diseases."

Studies such as those mentioned on the influence of heredity and of marital status on mortality point up the importance of familial studies in attempts to understand the distribution of the chronic diseases among the population. The epidemiological relationships indicated by such studies suggest possible bases for the further development of the practice of preventive medicine by clinicians and for control programs in health departments. The studies of Yerushalmy previously mentioned are a case in point. Further studies on the relationship between physiological state and subsequent mortality also seem desirable as, perhaps, furnishing leads for the development of sound preventive programs.

Little has been said about the relation of occupation to mortality although the increasing industrialization of the population makes this subject of increasing importance. The influence of socio-economic status on mortality is also of importance. The reader is referred to Dublin and others (1949) and to Sydenstricker (1933) for more detailed discussion.

## MORBIDITY

Any attempt to paint a picture of the state of health of a population will have completed only a very small portion of the canvas if only mortality is considered. Some of the most important causes of illness have a relatively low mortality—common cold, for instance—and the importance of others is minimized because they are reflected only indirectly in mortality data, e.g., mental diseases.

Knowledge of the extent and incidence of morbidity in the population, however, is far less complete than is that for mortality and, except for the notifiable diseases, there is no registration procedure comparable to that which exists for death.

**THE DEFINITION OF ILLNESS.** The primary problem in any attempt to gather information concerning illness in the population is that of defining what is to be counted as an illness. This problem does not exist in mortality statistics, since the fact of death is irrefutable. Moreover, it is to the interest of the family of the deceased to see that the fact of death comes to the attention of legally constituted authorities; therefore a machinery exists for gathering mortality information (see page 1350) quite apart from purely statistical considerations.

These conditions do not apply to the collection of morbidity statistics. When is a person ill? If, for example, one has a slight rhinitis which does not incapacitate him or cause him to lose time from work, is this to be counted as an illness? The suggestion may be made that one count only illness seen by a doctor. However, such an illness as the common cold, which is responsible for a considerable amount



of illness in the population, may never be seen by a doctor. A number of other definitions suggest themselves. What is actually counted will depend upon the purposes to be served by the data and upon the procedure by which they are collected. Various definitions have been adopted in different studies. Some include only illness lasting seven days or longer, others count all conditions resulting in time lost from work of one day or more, and still others use other definitions. Clearly, any estimate of the amount of illness in the population at a given time or of the rate at which illness develops in it will vary with the particular definition used.

Although the task of acquiring knowledge concerning morbidity in the population is by no means easy, there is a growing body of information on the subject which has been collected in a variety of ways.

**SOURCES OF DATA.** The nature of the various sources of information concerning sickness in the population and their historical development are reviewed in detail by Collins (1941). We shall attempt here to give only a summary of the procedures by which such information becomes available in the present day and to indicate the general nature of the findings. The reader is referred to Collins for an extensive bibliography on the subject.

The various procedures for gathering morbidity data can be grouped into two broad classes: (a) those in which the basic record is collected routinely, even though the morbidity data are only a by-product rather than the primary purpose of collecting the record, and (b) those procedures which are carried out on a one-time basis or, at least, if they involve successive repetitions, are essentially discontinuous or nonpermanent in character. The latter group has come into considerable prominence in recent years.

**THE REPORTABLE DISEASES.** The procedure by which physicians are required to report certain diseases to the health authorities when these diseases occur in their practice falls in the first category. At the present time, all states require the reporting of certain diseases although the list is not the same for each state (Fowler, 1944). The data are summarized periodically by the United States Public Health Service in *Public Health Reports*.

From the standpoint of obtaining a picture of the extent of illness in the population, there are serious deficiencies in these data in addition to the variation that exists in the diseases to be reported in the various states. There is evidence that the data collected in this manner understate the extent of the problem and, generally speaking, only the "epidemic" diseases are required to be reported, although in recent years there has been a tendency in some states to require the reporting of such diseases as cancer and rheumatic fever. The data collected are useful for establishing the general trend of specific diseases but cover only a very small portion of the problem of illness in the population.

**SICK BENEFIT ASSOCIATIONS.** Much of our knowledge of illness in the population in the past derives as a by-product from the records of sick benefit associations. In connection with the verification of an application for payment of a sick benefit, certain information is obtained, which includes physician's statement on the diagnosis and other facts about the illness. The records are usually fairly complete because of the financial considerations which hinge on the information. However, the data are not representative of the total population, since they refer only to a particular working group. In addition, payment is usually restricted to those cases lasting

more than a certain length of time—usually seven days. Such data have the advantage, however, that they can be related to a known population base and various types of illness rates can be computed.

**HOSPITAL RECORDS.** Hospital records are a third source of information on illness for which the basic records are collected routinely. These, of course, will refer only to those cases ill enough to be hospitalized. (Very little has as yet been done with out-patient statistics.) It is ordinarily difficult to relate the statistics of any one hospital to the population which it serves because this information is usually unknown, although in one or two isolated instances such a correlation has been made (Crosby, 1939). However, when data are collected from all the hospitals in an area, the population of the area may be used as the base for rates, provided nonresident cases are eliminated. Such a procedure was advocated as early as 1913 by Bolduan and even earlier by Florence Nightingale. The Hospital Discharge Study of the Welfare Council of New York City (Deardorff and Frankel, 1942) represents one of the first attempts of this kind in this country. Stocks (1950) describes a program in England to collect information in this manner which is made possible by the operation of the National Health Service. The widespread development of Blue Cross programs also provides a source of data on the hospital experience of a group of the population, although admission data from this experience are higher than in the general population because the financial obstacles to hospitalization have been to some degree removed. The experience of the Veterans Administration medical program also provides data on illness among a group of the population, but such data are difficult to relate to a known population base.

Other sources of routinely collected information are school absenteeism records and records of the illness experience of the Armed Forces.

Practically all of the sources of information in this first group are for a selected portion of the population—restricted with respect to age or economic status or severity of illness or type of illness or other factors. Although the data that are yielded by them are not representative of the population at large, nevertheless, they are useful in many ways. Knowing, for example, something of the nature of the selection sometimes permits the estimation of maximum or minimum values of the rate for the population in general. The data are useful to the administrator in charge of the specific program from which they arise in planning and evaluating the program, and, as in the case of the school population, they may give a fairly accurate picture of the illness experience of specific groups.

In the last two decades there has been an increasing realization of the need for more comprehensive morbidity data on the population as a whole. As a result of this need, several surveys and studies have been undertaken which have yielded valuable information. These surveys fall in the second class of procedures for gathering data—that is, in the class in which the data are derived from records which are essentially of a noncontinuous nature.

The earliest attempt in the United States to obtain information about sickness in the population in general was that made in conjunction with the 1880 census at the instigation of John Shaw Billings. A question was asked about the number of persons sick and unable to work on the day of the census. The reader will recognize that the resulting data furnished information on the *prevalence* of illness in the population (see page 1319). Since the census was taken as of June 1st, the seasonal



variation in illness was not taken into account. The next fairly comprehensive survey was that of the Metropolitan Life Insurance Company in 1915-1917, which was also a prevalence study but did include data on duration of the illness and, since it covered a two-year period, did allow for seasonal variation. The studies initiated in 1916 by the United States Public Health Service on pellagra in South Carolina mill villages began a series conducted under the auspices of this agency, among which is the classic one under the direction of Edgar Sydenstricker in Hagerstown, Maryland, in 1921. The study of South Carolina mill villages and the Hagerstown study mark the first attempts to obtain data on the *incidence* of illness in a population group by means of periodic visits at fairly frequent intervals and inquiry as to the occurrence of illnesses during the period between visits. In the Hagerstown study the canvassed population was visited at intervals of two months for a period of over two years.

In the early thirties the studies of the Committee on the Costs of Medical Care and the Health and Depression studies of the Public Health Service (1935) followed the general pattern of the Hagerstown study. However, the most extensive study to date from the standpoint of over-all coverage has been the National Health Survey of 1935-1936 (Perrott and others, 1939) which covered 2.5 million people in 83 cities. Data were also obtained on a little over 140,000 persons in 23 primarily rural counties to obtain some information on rural health. The data collected were confined to: (1) illnesses which result in inability to carry on usual activity for seven consecutive days or longer during the year prior to the enumerator's visit, and (2) serious physical handicaps and chronic diseases that were present but not necessarily disabling on the day of the visit.

Whereas the National Health Survey was extensive in coverage, the results of an intensive survey carried on over a five-year period from 1938 to 1943 in Baltimore with regular monthly interviews are of interest because the method of the study made for completeness of information and also tended to give proper weight to chronic illness in the total picture (Downes and Collins, 1940).

The introduction of sampling procedures by the Census Bureau in the 1940 Census and the subsequent use of such procedures to gain more current information about the population and the labor force has turned attention to the possibility of using these "current sampling" procedures to obtain information about the health of the population. Such information, however, is limited to prevalence data. Two such studies are reported by Sanders and Federman (1943) and by Woolsey (1950). The latter is of interest in that it harks back to the use of census procedures to gain the data, as did the initial attempt of Billings.

**Morbidity in the Population.** The picture of the health of the population afforded by these various sources is as follows:

**GENERAL.** A good general picture of the health of the population in urban areas is afforded by the data in Table 45-4. It is to be noted that the extent of illness may be measured in a variety of ways and that the numerical values obtained will be dependent upon the definitions of such terms as illness, disability, chronic disease, etc.

**THE PREVALENCE OF ILLNESS.** The percentage of persons disabled on the day of visit (4.4 per cent) in the National Health Survey was higher than that found in the study of the Metropolitan Life Insurance Company (1.9 per cent) and in

Table 45-4.\* Rates of illness according to several measures

Item	Type of Information	Rate
1	Percentage of persons disabled on day of visit <sup>a</sup>	4.4
2	Percentage of persons disabled for the whole 12 months immediately preceding visit <sup>a</sup>	1.2
3	Percentage of persons reported as having a chronic <sup>b</sup> disease or impairment <sup>c,d</sup> Illnesses disabling for a week or longer during the 12 months immediately preceding the visit: <sup>e,f</sup>	17.7
	Frequency per 1,000 persons:	
4	All illnesses	171
5	Acute	123
6	Chronic <sup>b</sup>	48
7	Diseases	45
8	Impairments <sup>c</sup>	2.9
9	Excluding persons disabled for the whole period	159
	Number of days of disability per person observed: <sup>g</sup>	
10	All illnesses	9.9
11	Acute	2.6
12	Chronic	7.3
13	Diseases	6.3
14	Impairments	1.0
15	Excluding persons disabled for the whole period	5.6
	Number of days of disability per case: <sup>g</sup>	
16	All illnesses	58
17	Acute	21
18	Chronic	154
19	Excluding persons disabled for the whole period	36
20	Percentage of workers <sup>h</sup> (15-64 years of age) who were reported to be "unemployable" by reasons of disability <sup>i</sup>	1.1

From The National Health Survey, Some General Findings as to Disease, Accidents, and Impairments in Urban Areas, by Rollo H. Britten, Selwyn D. Collins and James S. Fitzgerald. Public Health Reports, Vol. 55, No. 11, pp. 444-447, March 15, 1940. (Reproduced with permission.)

\* For explanation of table and chart references, see original source.

the Health and Depression study (2.3 per cent). This is partly due to the inclusive nature of the definition of illness, and partly, perhaps, to the fact that the National Health Survey figures refer to an average winter day. The prevalence figure obtained in Woolsey's study in February, 1949, for the civilian noninstitutional population 14 to 64 years of age was 4.7 per cent. A more detailed comparison of the rate in Woolsey's study with that of the National Health Survey by age groups shows a good agreement of the two sets of figures. The prevalence rates for disabling cases in the intensive study of Downes and Collins in Baltimore varied from about 3 per cent for the summer months to a high of about 5 per cent in February and March.

THE INCIDENCE OF ILLNESS. As has been emphasized, the illness rate of a population will vary with the type of survey and the definition of illness. Surveys conducted like the Hagerstown study and the Eastern Health District Study yield figures on the order of one case per person per year. "On the other hand, illnesses causing inability to work for seven consecutive days or longer will amount annually to only 125 to 200 cases per 1,000 persons; as the rates are higher for the very young, the old, and for those not gainfully employed, the working population will



average 75 to 125 cases per year but the total population of all ages will have a rate nearer 200 cases per year” (Collins, 1941).

The figures just cited measure the *frequency* of illness. They are average values. Some persons may have no sickness at all; others may have much more than one illness per year. One may also measure the *severity* of illness. This is usually expressed as days of disability per 1,000 persons observed (see Table 45-5, and Collins, 1941).

Table 45-5.\* Annual frequency of acute and chronic illnesses disabling for a week or longer,<sup>a</sup> according to age<sup>f</sup>

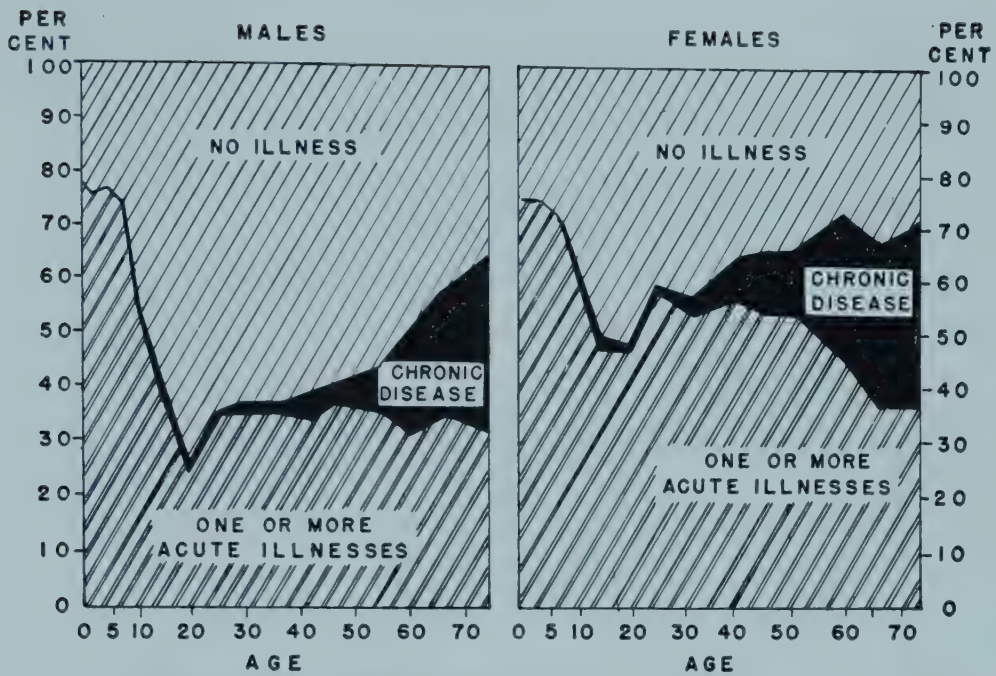
Age in Years	All illnesses	Acute	Chronic		
			Total	Disabled for 12 Months Immediately Preceding Visit	Other
Annual frequency per 1,000 persons					
All ages	171	123	48	12	36
Under 15	214	198	16	3	13
15-24	131	109	22	5	18
25-64	153	96	57	13	44
65 and over	279	102	177	63	114
Days of disability per case <sup>g</sup>					
All ages	58	21	154	(12 months by definition)	86
Under 15	27	19	130		82
15-24	42	21	141		82
25-64	69	23	147		84
65 and over	131	27	191		96
Days of disability per person observed per year <sup>g</sup>					
All ages	9.9	2.6	7.3	4.3	3.1
Under 15	5.7	3.7	2.0	1.0	1.1
15-24	5.4	2.3	3.1	1.7	1.5
25-64	10.5	2.2	8.4	4.7	3.7
65 and over	36.1	2.7	33.4	22.6	10.8

From The National Health Survey, Some General Findings as to Disease, Accidents, and Impairments in Urban Areas, by Rudo H. Britton, Selwyn D. Collins and James S. Fitzgerald. Public Health Reports, Vol. 58, No. 11, pp. 444-447, March 15, 1945. (Reproduced with permission.)

\* For explanation of table references, see original source.

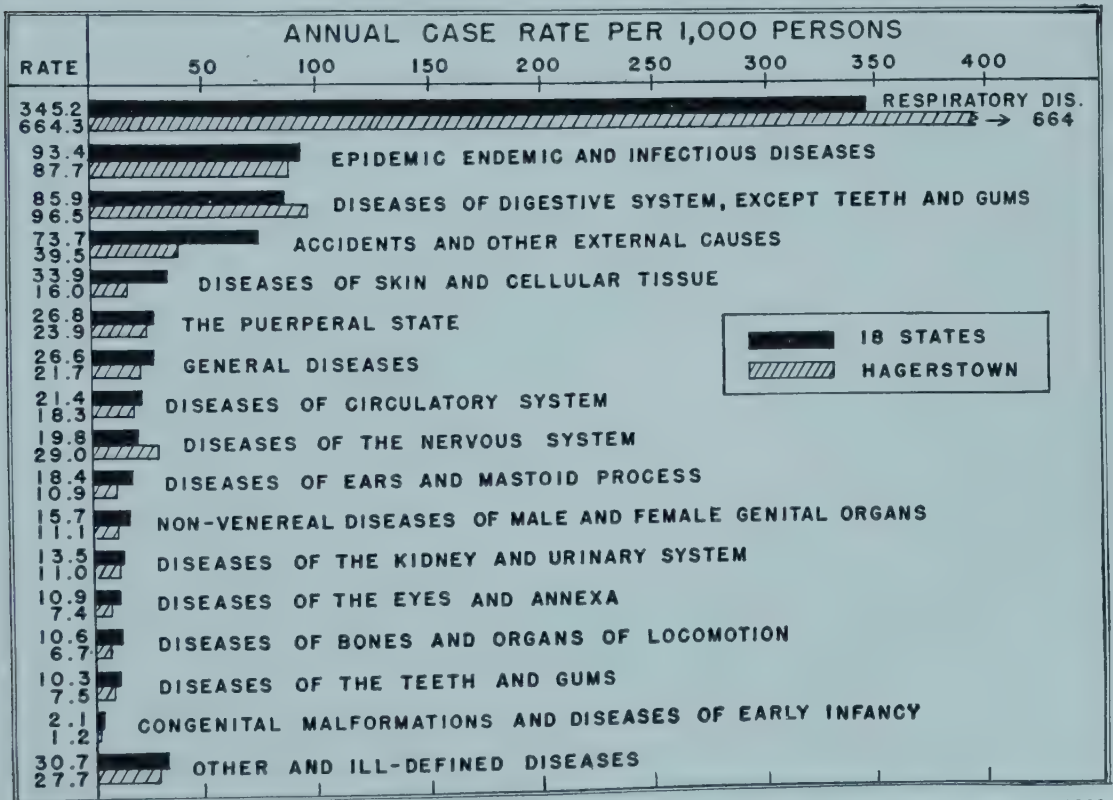
THE VARIATION OF ILLNESS WITH AGE.\* The incidence of illness is high in early life and in old age, but the severity of illness is least in childhood. (Table

\* The reader is referred to Collins for a consideration of the causes of illness at different ages.



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Fig. 45-9. Proportion of the total population by sex who (1) reported no illness, (2) reported the presence of chronic disease, and (3) reported only one or more acute illnesses in 1,243 canvassed white families, Eastern Health District of Baltimore, 1938-1939.



Reproduced with permission from Pub. Health Rep., 48:12, 1933.

Fig. 45-10. Annual incidence of illness from broad groups of causes in canvassed families in 18 states and in the Hagerstown survey.



45-5). The childhood diseases are largely acute in nature and the proportion of illnesses classified as chronic increases with age. Figure 45-9, taken from the intensive study of families in the Eastern Health District, shows these same general facts in a different way and contrasts the sexes.

Table 45-6.\* Annual frequency and disability rates of illnesses disabling for one week or longer,<sup>e</sup> by diagnosis<sup>f</sup>

Diagnosis	Frequency (per 1,000 Persons)	Days of Disability per Person Observed <sup>e</sup>
All diagnoses <sup>1</sup>	171	9.9
Communicable diseases:		
Common communicable diseases of childhood	26.3	.55
Other	2.8	.13
Cancer and other tumors	2.9	.29
Diabetes mellitus	.89	.15
Rheumatism and allied diseases	5.9	.71
Cardiovascular-renal diseases	11.0	1.34
Nervous and mental diseases	5.4	1.02
Diseases of ear and mastoid process	2.0	.068
Diseases of respiratory system:		
Tuberculosis (including nonrespiratory)	1.3	.32
Pneumonia (all forms)	4.7	.18
Tonsillitis (including tonsillectomies)	9.9	.14
Other diseases of respiratory system (colds, influenza, etc.)	35.0	.84
Diseases of digestive system:		
Appendicitis (including appendectomies)	5.0	.20
Hernia	1.0	.094
Diseases of teeth, mouth, and gums	.52	.017
Other diseases of the digestive system	7.7	.54
Diseases of thyroid gland	.62	.061
Anemia	.47	.067
Hemorrhoids	.72	.033
Varicose veins	.38	.040
Diseases of bladder, urethra, urinary passages, and male genital organs	1.3	.10
Diseases of female genital organs and complications of pregnancy	3.2	.22
Confinements	15.0 †	.38
Diseases of skin and cellular tissue	2.0	.11
Accidents	15.4	.75
Orthopedic impairments	2.5	.86
Blindness and deafness	.40	.14
Other and ill-defined diagnoses	6.6	.58

From The National Health Survey, Some General Findings as to Disease, Accidents, and Impairments in Urban Areas, by Rollo H. Britten, Selwyn D. Collins and James S. Fitzgerald. Public Health Reports, Vol. 55, No. 11, pp. 444-447, March 15, 1940. (Reproduced with permission.)

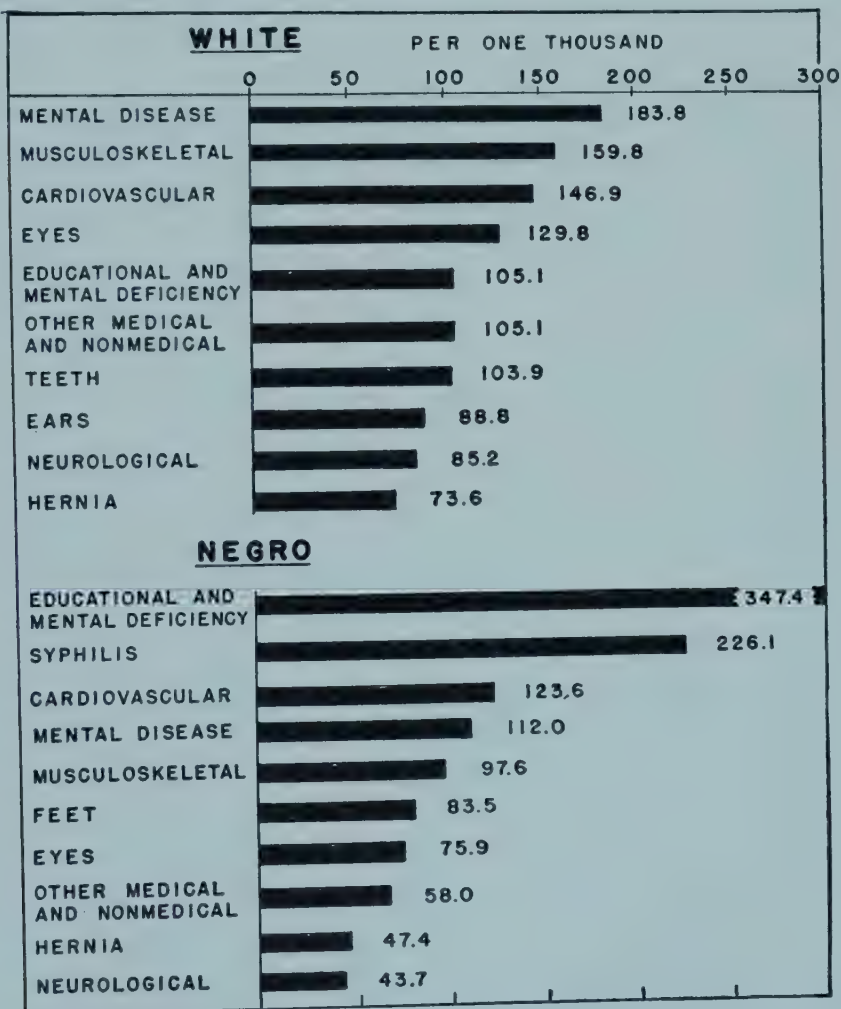
\* For explanation of table references, see original source.

† Live birth rate is 14.0 per 1,000 persons.

THE CAUSES OF ILLNESS.\* The findings of the Hagerstown Survey and of the study of 9,000 families with respect to the causes of illness are contrasted in Figure

\* The reader is referred to Collins for a consideration of the causes of illness at different ages.

45-10. The data for the National Health Survey, which, it will be remembered, pertained only to illnesses of seven days' duration or longer, are presented in Table 45-6. The picture which emerges from these studies indicates that the most frequent causes of illness in the population are the respiratory diseases, followed by the infectious diseases and epidemics including the common communicable diseases of childhood, and then the diseases of the digestive system. Accidents, too, are an important cause of illness. When attention is focused, however, on the amount of disability for which a particular class of disease is responsible, the cardiovascular-renal diseases head the list, followed by the nervous and mental diseases. Orthopedic impairments were found to have the third highest disability rate in the National Health Survey and, measured in these terms rather than frequency of illness, diseases of the respiratory system had dropped to fourth place. Accidents still remain a major contributor to total days of disability.



Adapted from data in Physical Examinations of Selective Service Registrants in the Final Months of the War, Medical Statistics Bulletin No. 4, Washington Headquarters, Selective Service System, June 1, 1946.

Fig. 45-11. Rejection rates per 1,000 registrants physically examined for the armed forces according to the principal causes of rejection and according to race, World War II.

Because of their special interest, and because they pertain to a particular age group in which the over-all illness rate is low, the findings of Selective Service examinations in World War II are presented in Figure 45-11. The importance of



mental and cardiovascular disease even in this relatively young age group is to be noted.

The idea that these findings or, at least, their forerunners in young men might have been discoverable earlier and possibly prevented has been explored by Ciocco and others (1941), using the records of physical examination of Hagerstown school children during the period 1922 to 1928 and classifying them as to whether the children examined were in later years accepted or rejected on physical examination by draft board physicians. The general findings of this study were that "a relatively large number of the selectees who have been rejected because of defective dentition and vision already gave evidence of the same defects 15 years ago when they were in elementary school" and "growth as measured by weight, posture, and the physician's estimate of the state of nutrition . . . are useful as crude predictive indexes of adult physical development." Further studies of this type are needed as a background for the development of sound programs of preventive medicine.

Table 45-7.\* Annual frequency of acute and chronic illnesses disabling for one week or longer<sup>c</sup> (per 1,000 persons) as related to economic status<sup>f</sup>

Annual family income and relief status	All illnesses	Acute	Chronic <sup>b</sup>
All incomes . . . . .	171	123	48
Relief . . . . .	232	160	72
Nonrelief:			
Under \$1,000 . . . . .	176	120	56
\$1,000 to \$1,500 . . . . .	155	117	38
\$1,500 to \$2,000 . . . . .	146	111	35
\$2,000 to \$3,000 . . . . .	145	110	36
\$3,000 to \$5,000 . . . . .	145	109	36
\$5,000 and over . . . . .	146	107	39
Relief and nonrelief under \$1,000 . . . . .	200	138	63

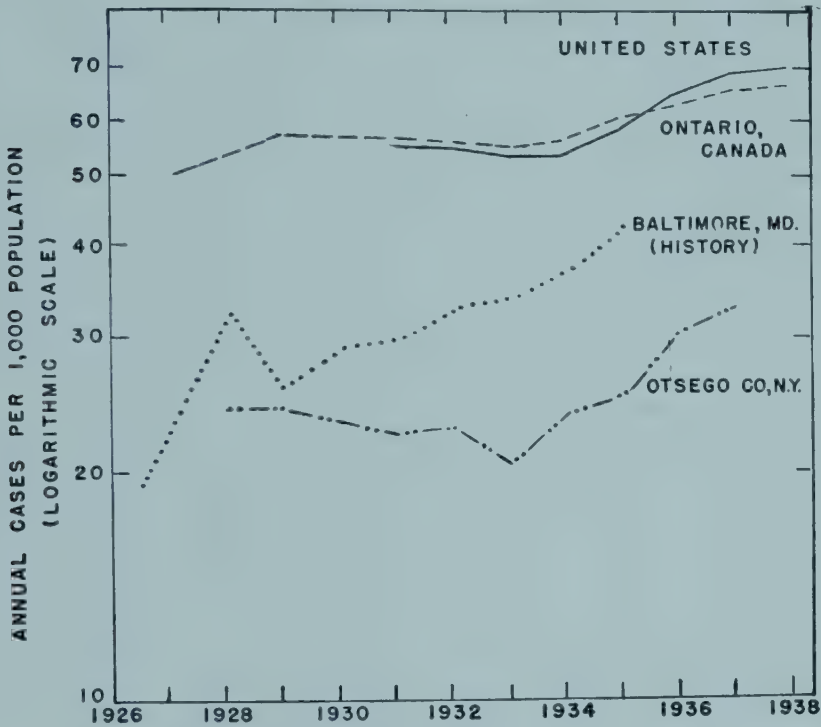
From The National Health Survey, Some General Findings as to Disease, Accidents, and Impairments in Urban Areas, by Rollo H. Britten, Selwyn D. Collins and James S. Fitzgerald. Public Health Reports, Vol. 55, No. 11, pp. 444-447, March 15, 1940. (Reproduced with permission.)

\* For explanation of table and chart references, see original source.

**ILLNESS AND ECONOMIC STATUS.** The relationship of illness to economic status is shown in Table 45-7. In general, diagnoses of an acute nature seem to be less responsible for the high rates of the low income group than those of a chronic nature. These findings agree in general with those of other studies. The relationship of illness to other socio-economic factors such as urbanization, housing, occupation, etc., are discussed by Sydenstricker (1933), Downes (1948), Britten and Altman (1941), and Vernon (1939).

**THE EXTENT OF HOSPITALIZATION.** Data on the extent of hospitalization are relatively meager, due in part to the difficulty of relating admission data to the proper population base. Figure 45-12 shows the trend of admission rates as found in various studies. All of the curves show a rising admission rate. In a study of

the hospital experience of two counties in rural Michigan (Sinai and Paton, 1949) which extended over the period 1940 to 1945, this rising trend was also evident, the rates for one county increasing from 50 per 1,000 population to 82, and in the other from 49 to 75. During this time period, the proportion of hospitalizations



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Fig. 45-12. Annual hospital admissions per 1,000 population (excluding newborn and admissions to mental and tuberculosis hospitals), United States, 1931-1938; Province of Ontario, Canada, 1927-1938; 2,444 families living in the Eastern Health District, Baltimore, in 9 hospitals, 1926-1935; resident discharges from Mary Imogene Bassett Hospital, Otsego County, New York, 1928-1937.

paid for by Blue Cross increased markedly. The hospital discharge rate for the Saskatchewan Hospital Services Plan (Health Services Planning Commission, 1947) for the first six months of 1947 was 140 per 1,000 population. This figure, however, must be interpreted in the light of the fact that the system is a tax-supported hospital care insurance plan. The rate in the 9,000 Families Study was 61.6 per 1,000 population per year over the period 1928 to 1931.

There is considerable variation in hospitalization rates by sex, females having a much higher rate than males. However, when hospitalizations of females for genital and puerperal conditions are eliminated, the over-all rate for females is not very different from that for males. The curve for the incidence of hospitalization by age shows two peaks—one in the early school ages and another in the child-bearing ages. The rates then fall off somewhat, to increase again at the age of about sixty. In the Baltimore study (Councell, 1941) over 60 per cent of all admissions were due to tonsillectomy, delivery, accidental injury, appendicitis, and female genital diseases.

From these data it is clear that the most frequent causes of hospitalization are not the most frequent causes of illness or even of mortality. Nevertheless, such data



are of value in planning for hospital facilities and in focusing attention on problems of preventive medicine.

**PREVALENCE OF IMPAIRMENTS.** The National Health Survey found approximately 2 per cent of the population with a permanent orthopedic impairment of such a serious nature that the individuals were considered to be partially or completely crippled, deformed, or paralyzed. A little less than 1 in 1,000 persons was found to be blind in both eyes. It is believed that this figure represents total or practically total blindness.

Dublin and others (1949) in their chapter on longevity and physical condition discuss the findings of life insurance companies as to the presence of medical impairments such as overweight, heart disease, glycosuria, etc., among presumably healthy individuals. They compare the observed mortality among individuals found to have such impairments on examination with that expected based on an appropriate life table. The reader is referred to their book for an interpretation of the results. Here we shall only say that many of the impairments investigated were associated with a high *excess* mortality.

The kind of question asked concerning impairments has been studied in relation to the presence of chronic sickness by Ciocco (1946). The data in this study were not subject to the selective factors of the life insurance material, the observations on sickness having been made in the original Hagerstown surveys of Sydenstricker. The general question was as follows: What is the subsequent mortality of individuals found to have chronic disease in the initial survey as compared with those who were free of chronic disease at that time? It was found that persons with cancer, tuberculosis, and the cardiovascular-renal diseases died, in the 20-year interval of the study, at a greater rate than persons of comparable age and sex with no chronic ailment in the initial survey. There was no excess mortality, however, for those persons found to have neuritis, rheumatism, and certain respiratory conditions at the beginning of the 20-year interval.

**FUTURE NEEDS.** It has been indicated that "premises for action" directed towards improving the health of the population would, perhaps, become clearer as man's relationship to his total environment is more fully understood. The results of various statistical approaches to the exploration of this relationship have been outlined in this chapter. In addition to providing factual information, these approaches indicate some of the tools available to probe the vast areas which still remain unexplored.

In the study of problems associated with an aging population, the technic of making observations on a group of individuals and then observing the same individuals at a later date appears promising. Mention has already been made of the subsequent mortality of individuals having chronic disease as contrasted with those not having such chronic disease, and of the studies by life insurance companies of the relationship between impairments and mortality. The relationship of such impairments or of physiological defects to subsequent morbidity is as yet largely unknown. The study of the findings of school health examinations among those accepted and rejected many years later by Selective Service examinations bears on this last point. More studies of this kind are needed. They would seem to be of particular importance in relation to programs aimed at prevention.

A second area in which further work would appear likely to be fruitful is that

concerned with the association of various familial factors with the occurrence of disease. There is mounting evidence of familial concentration of such chronic diseases as cancer, diabetes, rheumatic fever, etc. The further study of factors influencing such concentration and the exploration of the possibility of familial concentration of other diseases may, at the very least, be expected to permit health authorities to define more closely the groups and individuals requiring special attention.

The relationship of economic factors to health can be studied adequately only through the family unit, since it is the only unit with both biological and social significance. Referring again to the study of the findings on school health examinations and their relationship to the Selective Service examinations, we may ask whether the individuals found to have defects on the school health examinations acquired these as the result of such influences as nutrition and housing, or whether they were largely the result of their hereditary make-up. These are factors the effects of which are obviously influenced by the family environment and, therefore any attempt to study their influence must begin with a consideration of the family unit.

The several investigations just cited have a common element of considerable significance for the further study of the factors influencing the health of the population. They all proceed from a population group of some kind. The school health and Selective Service study was not limited to those individuals having defects but started with all school children and subsequently divided them into the two groups, with and without defects. Exploration of the familial concentration of diseases has also been most profitable when it has proceeded from a general population group. If we are to learn anything about what has been termed the "epidemiology of health," it is essential that the importance of beginning with the population group be fully appreciated.

The last few decades have witnessed considerable advances in our knowledge of the health of the population. Not only have we added to our factual information, but our knowledge of how to get at the facts has also increased. There is hope, therefore, that the future will shed light on many areas which, if not altogether dark at the present time, are, nevertheless, a murky gray.

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# Section Nine

## PUBLIC HEALTH ORGANIZATION AND ACTIVITIES

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### 46

#### NATIONAL HEALTH SERVICES

The term "public health" has had many and varied interpretations at different times in different countries and under different philosophies. The most generally accepted definition in the United States at the present time is that of Winslow who defines public health as "the art and science of preventing disease, prolonging life, and promoting physical and mental efficiency through organized community effort." Public health administration might therefore be defined as the application of available knowledge to that end. The development of public health as a science or as an art has been an evolutionary process drawing knowledge from many fields of science, coordinating and integrating the various parts to accomplish the end of improving man's health. It is a sector of social science.

The administration of a public health program requires some competence in a number of seemingly unrelated branches of science. President Dodds of Princeton University, in a discussion of the expert in government, quoted Brooks Adams as defining administrative ability as "the capacity of coordinating many and often conflicting energies in a single organism so adroitly that they shall appear as a unity. This presupposes a power of recognizing a series of relations between numerous social interests with all of which no man can be intimately acquainted. It is possibly the highest faculty of the human mind."

The health of the people has long been recognized as a proper concern of government. Throughout recorded history governments have, within the limitations of available knowledge, assumed responsibility in a varying degree for the protection of the health of the people. The motives of government assuming this responsibility have not always been the same. In a feudal system the primary purpose may have been to maintain an adequate number of fighting men for defense against an aggressor or to more effectively dominate a neighboring people. In an enlightened society the motive is presumably a more altruistic one.

The nature of governmental activity in the interests of public health has changed markedly over the years. The earliest movement was primarily an effort to prevent the introduction of epidemic disease into the group by restriction of movements of peoples through isolation or quarantine. Efforts were also made to prevent the spread of infectious disease within the group through the utilization of the police power of the state. As knowledge of sources and modes of infection increased, the public health activities of government related more and more to the control of the

environment, the extent and the nature of activity in this field depending upon the character of the community to be protected. In urban communities it was found necessary for government to control the public water supply to be assured of an adequate quantity and of a safe sanitary quality of the water consumed by the citizens. Controls over the production and distribution of milk and many other foods have been found necessary. The control of the disposal of human wastes is essential to the health of the people; this has led to the development of extensive sewerage and drainage systems and, in many instances, to the treatment of such wastes in a manner that will prevent the occurrence of nuisances or the transmission of disease through this means. In parts of the world the control of insect breeding for the protection of the health of the people is a major governmental activity.

During the past 50 to 75 years great advances have been made in the protection of the public health through the control of the environment. During this period there has been a changing emphasis. This has been an era of social legislation and social progress. Particularly in western Europe and the Western Hemisphere social reforms have been taking place in which public health has been an important issue. Governments have become greatly interested in child welfare, maternal welfare, improvement in housing, and aid to the physically handicapped, as well as in the special disease problems such as tuberculosis, venereal disease, cancer, heart disease, and mental illness. The development of these interests has materially altered the character of the organization within government for the protection of the public health. The emphasis in governmental participation has changed from the impersonal approach through environmental controls to the personal approach through preventive medicine for the individual.

## THE NATIONAL HEALTH ORGANIZATION

The responsibility for a public health program is shared in most countries by the national government and the various political subdivisions of the nation. The degree of responsibility of the national government depends largely upon the political structure of the national and local governments. In a strongly centralized government there is a tendency for the major responsibility to be vested in the national government whereas in those countries where local autonomy has been retained health services, as well as other services of government, are implemented to a greater degree at the local level.

England might be cited as an example of a strong centralized authority in the national government. The Ministry of Health Act of 1919 created a Ministry of Health to which were assigned all health activities of the national government previously administered by other branches of government. The Ministry of Health is a major branch of the national government headed by a minister selected by the party in power, assisted by a permanent secretary who is a civil servant, and a chief medical officer, both selected on the basis of merit. The Ministry of Health has very broad powers of supervision over the local health authorities. Since the enactment of the national medical service act of 1947 the Ministry has had direct responsibility not only for the traditional public health services but for general medical service as well.



Historically, the national health services in Italy might be cited as an example of the opposite extreme in which the primary responsibility for health services has been at the local level. Until quite recently the local or communal health organization was primarily responsible for health services under a somewhat nominal supervision of provincial and national health authority, the national organization having a status of a "high commission" in the department of the interior. Another evidence of the lack of a strong central authority in Italy was the delegation of many of the major responsibilities for public health activities to voluntary agencies supported by large grants from the national government without a corresponding voice in the program. The almost world-wide tendency toward the concentration of taxing powers at the national level has a tendency to reduce local autonomy and this is apparent in Italy at the present time.

Another pattern of organization which may be observed in a number of different countries is a combination of public health with other more or less directly related activities of government into a department or ministry. An example of this type may be observed in the Norwegian Department of Public Assistance which administers a program of public health, welfare, and insurance.

## NATIONAL HEALTH SERVICES IN THE UNITED STATES

The administration of health services in the United States differs considerably from that of other nations primarily because of the different political structure of the nation. The national government has only those powers delegated to it by the sovereign states. The Constitution of the United States does not specifically delegate powers to the federal government in the health field with the exception of provisions for interstate and foreign quarantine. However, Article 1, Section 8, of the Constitution authorizes the federal government "to lay and collect taxes, duty, imposts, and excises. . . to provide for the defense and general welfare." The authority for the administration of national health services is derived from this provision for the federal government's interest in the general welfare. Under this authority, health services were developed over the years in various departments of the federal government, until recently with no central coordinating agency with the exception of the creation of a national board of health in 1879. This board, however, never actually functioned as a national health agency and went out of existence four years later.

### THE DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

The Department of Health, Education and Welfare came into being as a result of legislation enacted by the 83rd Congress in 1953. This legislation gave departmental status to those activities of the federal government previously brought together and constituting the Federal Security Agency, which was established in 1939 as a result of the approval of a governmental reorganization plan of that year. The objective of that reorganization was "to group together those agencies of the government whose major purpose was to promote social and economic security, educational opportunity and the health of the citizens of the nation." The agencies which were brought together included the Social Security Board, including the United States Employment Service; the Office of Education; the United States Public Health Service and the federal functions of the American Printing House for the Blind. In 1940, further approval of reorganization plans resulted in the transfer of the Food and Drug Administration, St. Elizabeth's Hospital, Freedman's Hospital and the federal functions relating to Howard University and to the Columbia Institution for the Deaf to the Federal Security Agency. In 1946, further reorganization transferred the Children's Bureau with all of its functions except those relating to child labor to the Social Security Administration within the Federal Security Agency and transferred the Office of Vital Statistics from the Bureau of the Census to the United States Public Health Service. These various reorganization plans, culminating in the creation of the Department of Health, Education and Welfare,



brought under one general direction the major health activities of the federal government; it left many minor health activities distributed to various departments. In addition to the Veteran's Administration and the Armed Services, a number of departments of the federal government maintain rather extensive services directly or indirectly pertaining to health. In the Department of the Interior, the Office of Indian Affairs administers a program of medical care and public health among the Indian wards of the government. This function was transferred to the United States Public Health Service, within the Department of Health, Education and Welfare, in 1955. The Department of the Interior maintains a Bureau of Health and Safety directed primarily toward accident prevention. The Department of Agriculture, through the Bureau of Animal Industry and the Bureau of Entomology and Plant Quarantine, carries out programs for the control and prevention of disease and parasitic infections of domestic animals and for insect vector suppression. The Department of Agriculture also operates a program of inspection for all meat sold in interstate and foreign commerce, establishes standards of various food products and has control of insecticides. The Labor Branch of the Department of Agriculture provides medical and health services for seasonal workers and its Bureau of Human Nutrition provides rather extensive service in this field. The Farm Security Administration of the Department of Agriculture operates a medical care program among low-income farm groups. A number of other departments or agencies in the federal government carry on minor health activities.

### THE UNITED STATES PUBLIC HEALTH SERVICE

The United States Public Health Service is the principal agency of the federal government concerned with the development of public health programs. The Service is at present a division within the Department of Health, Education and Welfare. Prior to 1953, it was a division of the Federal Security Agency which was created in 1939 as a result of the approval of a governmental reorganization plan of that year. For approximately 140 years, the Public Health Service was a bureau in the Treasury Department, having been created as a marine hospital service in 1798. The work of the Public Health Service falls into three major categories, research, medical and hospital services and public health practice. The Service also administers financial grants to the states for general and special public health services and for the construction of hospitals, health centers, and other medical facilities. Grants are also made to public and private nonprofit research institutions for medical research and the training of scientists. The research programs of the Public Health Service include laboratory, clinical, epidemiological, engineering, statistical and administrative studies, all focused on contemporary health problems. Highly qualified scientists conduct the studies and facilities of the Service in the field and in laboratories of other institutions under cooperative arrangements. The Service also helps to increase the number of medical and public health scientists through fellowships and traineeships for qualified students. Public Health Service Research Grants augment the nation's medical research effort. These grants help support the investigations of research scientists in their own institutions. Grants are also made for the training of professional personnel in certain specialized fields such as mental health, cancer and heart disease.

The Public Health Service provides medical and hospital care for certain groups of people declared eligible by Congress to receive such care. Among these are the seamen of the American Merchant Marine, personnel of the United States Coast Guard, American and Alaskan Indians and civilian employees of certain branches of the government. The Service provides medical personnel for the ship and shore establishments of the United States Coast Guard and the Maritime Administration, for the prisons and reformatories of the Department of Justice, for the health programs of the International Cooperation Administration and for several other federal agencies. It administers the nation's foreign quarantine laws and regulations and conducts medical and psychiatric examinations of immigrants seeking admission to the United States. The Service provides leadership and technical assistance to states and local communities in the development of public health programs. It develops and promulgates standards for the protection of the public from milk- and food-borne diseases. In cooperation with state and local health departments it develops and tests new methods in the prevention and control of disease. One of the important functions of the Public Health Service is the licensing of the manufacturer of biological products. It collects and distributes national vital statistics and conducts special studies of health problems.

The Service is organized on semimilitary lines, is headed by a surgeon general, and consists of corps of commissioned officers and civil service employees. It was reorganized by an act of Congress in 1944, Public Law 410, known as the basic public health service law, which brought together into one statute all of the previous legislation concerning the Public Health Service and established the organization approximately as it is today. By this act there are four statutory bureaus: the Office of The Surgeon General, the National Institutes of Health, the Bureau of Medical Services and the Bureau of State Services.

In carrying out its assignments for the fiscal year ending June 30, 1954, the Public Health Service, for example, was responsible for administering about \$221,000,000. Two thirds of this amount, approximately \$132,000,000, was allocated to others in the form of grants to the states, private institutions, and individuals outside of the federal government. This sum was distributed as follows: \$65,000,000 for grants for the construction of hospitals and health centers, \$43,000,000 for grants to support research and training, and \$24,000,000 for grants to the states to maintain and improve health services. The remaining one third, \$89,000,000, went toward the direct operations of the Public Health Service, that is, administration of its hospitals and clinics, enforcement of foreign quarantine, laboratory and field research, collection and reporting of vital statistics and technical assistance to states and localities.

To carry out its mission, the Public Health Service employed in 1954 approximately 15,000 full-time personnel representing over 250 occupational specialties and including many health and related professions. Of these, about 2,500 were officers of the Public Health Service Commissioned Corps and 12,500 were career civil service employees. The Commissioned Corps, a long-established quasimilitary career organization, includes many of the professional personnel of the Service such as physicians, dentists, sanitary engineers, nurses and others. Commissioned officers undertake their careers in the Service early in their professional lives and like officers in the Armed Forces are commissioned in rank by the President with



the approval of the Senate. The chief officer of the Public Health Service is The Surgeon General, who is a member of the Commissioned Corps and is appointed by the President for a four-year term. The Deputy Surgeon General and Assistant Surgeons General, including the dental, engineer and nurse officers, of the Service are appointed by The Surgeon General from the Corps.

**Office of The Surgeon General.** The Office of The Surgeon General functions as a bureau of the Public Health Service under the immediate supervision of the Deputy Surgeon General. The bureau is responsible for the general administration of the Public Health Service and is concerned with policy development, program coordination and administrative staff services. This bureau consists of four divisions. Three of these, namely, finance, personnel and administrative services, provide administrative and managerial services for the organization. The fourth division is that of Public Health Methods.

The Division of Public Health Methods provides staff services for The Surgeon General and deals with a great variety of problems. The work of the Division falls into three major categories: (1) the identification and definition of current and future health problems; (2) the measurement of these problems against available facilities, health personnel and organization; and (3) the development of methods for judging the effectiveness of public health programs. One of its major responsibilities is the collection and analysis of data either through established sources or through original investigation or studies. This Division also gives assistance to various bureaus and divisions of the Public Health Service and to other governmental and nongovernmental health agencies. The Division of Public Health Methods also edits and publishes Public Health Reports, the official journal of the Service, which carries discussions and original articles in the general field of public practice and administration.

The Division of International Health cooperates closely with other agencies directly concerned with world health. The agencies with which the Public Health Service works closely on international health matters are the Department of State, through its International Cooperation Administration; the World Health Organization, a specialized agency of the United Nations; the Pan American Sanitary Bureau; and the Institute of Inter-American Affairs. This Division also assists in the recruitment of technical and health personnel for these activities and in some instances loans personnel for missions in international health work.

**The National Institutes of Health.** The National Institutes of Health had their origin in the Hygienic Laboratory, created in 1930. As the original name implies, this laboratory was developed to carry out research activities primarily in the field of infectious diseases. The original Hygienic Laboratory has been expanded and now is represented by the Microbiological Institute. The functions of the various institutes are to conduct and to support research into the cause, diagnosis, prevention and treatment of the diseases of man.

The Director of the National Institutes of Health has the responsibility for formulating service-wide research policies and coordinating research activities. An Inter-Bureau Research Planning Council was developed to insure balance and integration of the research program in all parts of the Service. The National Institutes of Health are located in Bethesda, Maryland, a suburb of Washington, D. C. In 1955, they were composed of seven research centers, all of which were physically

related clinical centers. Space in the clinical center has been allocated, and studies of cases in the major disease areas are under way.

The National Cancer Institute was established in 1937 and was the first of the specialty institutes created by Congress. The pattern for federal aid to medical research and training was established in the same law. The work of the Institute is divided into two major parts: (1) the increasing of basic knowledge of cancer, and (2) the application of present knowledge to the prevention of death from this disease. The creation of a mental health program of the Public Health Service dates back to 1946. At that time there was authorization also for the National Mental Health Institute, which came into being in 1949. The National Heart Institute and the National Institute for Dental Research were created in 1948. In 1950, the Congress passed legislation authorizing the development of the Institutes of Arthritis and Metabolic Diseases and the Institute of Neurological Diseases and Blindness. In setting up the Institute of Neurological Diseases and Blindness, it was specified that studies should include multiple sclerosis, epilepsy, cerebral palsy and blindness.

The laboratories of the National Institutes of Health are among the finest in the world. The recently completed isotope laboratory is one of the few radioscope laboratories in the United States designed solely for medical research. This new laboratory provides ideal working conditions, including the most elaborate devices and the most complete opportunities for investigation in this field. In order to provide opportunities for medical research, particularly in the study of chronic disease, the 500-bed clinical center has been developed. In this clinical center approximately twice as much space is devoted to laboratory investigation as to patient care.

The Division of Research Grants and Fellowships of the National Institutes of Health administers a vast program of aid to research in institutions other than the National Institutes. The major objectives of a research grants program are: (1) to expand research activities in medical schools, hospitals and other institutions; (2) stimulate research in smaller institutions where such programs have been limited or nonexistent; (3) to encourage investigators to undertake research in neglected fields; and (4) to provide training for scientific personnel. To insure scientific freedom and promote the highest quality in research, the recipient of a grant agrees to pursue his research project and to publish his findings independently. Grants are awarded only upon recommendation of the appropriate National Advisory Council authorized by Congress and composed of leaders in the medical sciences, education and public affairs. These councils also advise The Surgeon General on policy within the legislative framework of the program. The Advisory Council works through study sections consisting of panels of outstanding authorities in major medical research areas. The research fellowships program of the Public Health Service is administered by the National Institutes of Health and designed to help increase scientific manpower of the country. Fellowships provide financial assistance to the most able and promising young scientists during their training period, encouraging them to enter a career of research in medical and allied fields. The awards are made on a competitive basis upon the recommendation of committees composed of outstanding scientists. The traineeship program is designed to increase the number of qualified workers engaged in specialized clinical fields. The program of teaching grants in medical fields is designed to assist medical students in obtaining broader



knowledge in the field of medicine. These grants are largely the development of courses in heart disease, cancer and mental illness. All of the nation's medical schools are now contributing to the cancer teaching grants program.

**The Bureau of Medical Services.** The Bureau of Medical Services includes the Divisions of Hospitals, Hospital Facilities, Medical, Dental and Nursing Resources, Foreign Quarantine and Federal Employee Health; through these various divisions it carries out the major medical functions of the federal government. The Division of Hospitals operates the United States Marine Hospital System consisting of 22 hospitals varying in size from 30 to 1,400 beds. These include two tuberculosis sanatoria and the National Leprosarium. In addition to the Marine Hospitals, two hospitals are maintained primarily for the treatment of narcotic addicts but also admit neuropsychiatric patients under certain circumstances. With these facilities, staffed by some 6,000 employees, the Division provides more than two million days of care annually in its hospitals. Outpatient departments of hospitals record approximately 500,000 visits and a full-time clinic services another 45,000 each year. The larger institutions have been approved for interne and residency training of physicians and dentists. The hospitals also provide training programs in other fields related to medical care, for personnel such as medical record librarians, practical nurses and nurse anesthetists. One of the major activities of the Division of Hospital Facilities is the administration of a National Hospital Survey and Construction Program. Under terms of legislation enacted by Congress, the Division of Hospitals, with the advice and assistance of the Federal Hospital Council, is responsible for administering the Hospital Survey and Construction Act of 1946 as well as the 1954 extension of that Act. These activities include approval of official state construction plans, financial assistance and technical advice, and leadership to state and local governments and to nonprofit organizations. The objective is to help communities to measure and meet their needs for hospitals and health facilities. As of June 30, 1954, approximately 2,300 projects had been approved under this program. These projects have added 109,000 hospital beds and almost 500 health centers to the nation's facilities. Total construction under the program amounted to an expenditure of \$1,849,000,000, of which the federal share will be approximately \$618,000,000. The Hospital Construction Program has been directed primarily toward the improvement of general hospital facilities. In 1954, however, Congress broadened the program by authorizing surveys and earmarked appropriations for chronic disease facilities, nursing homes, diagnostic and treatment centers and rehabilitation facilities. In the future, therefore, increasing emphasis will be placed on the construction of facilities providing long-term care and medical services for the aged, rehabilitation services and medical care for ambulatory patients.

The Division of Foreign Quarantine administers the quarantine laws and regulations of the United States; it also acts as the medical branch of the Immigration and Naturalization Service, the Commission on Displaced Persons and the Department of State. All persons seeking entry into the United States as immigrants for travel, study or business have some type of examination. During the fiscal year 1949-1950, 1,500,000 persons passed through United States ports of entry and border stations, including American citizens, and were inspected for the presence of quarantinable disease. Displaced persons are examined at resettlement centers prior to admission to the United States. Inspection of ships and aircraft arriving at port of entry from other countries is a part of the foreign quarantine procedure.

**The Bureau of State Services.** The Bureau of State Services provides consultation, technical assistance and financial aid to state and local health services in many different fields. Many of the divisions of this Bureau investigate new public health technics and conduct demonstrations or pilot programs for the development of new and better methods of administering public health activities. The Bureau also lends specialists and technical personnel to state and local health depart-

### THE DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

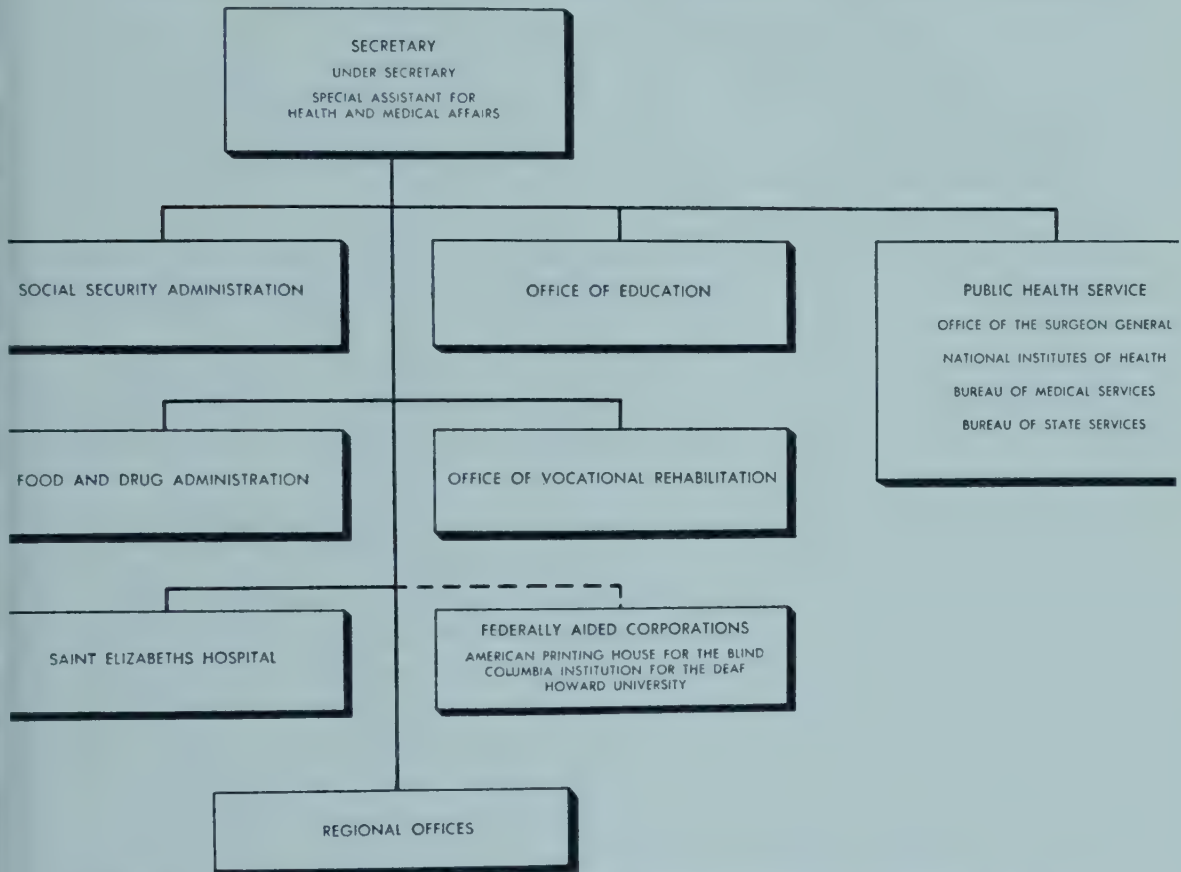


Fig. 47-1. Organizational chart—Department of Health, Education and Welfare.

ments to help solve specific problems and conducts training courses, seminars and educational programs for state and local personnel. It collects and publishes health statistics of value to state and local health departments. The Bureau is made up of 16 divisions, each of which offers service to the state and local health departments. These include the divisions of State Grants, Public Health Education, Public Health Nursing, Sanitation, Water Pollution Control, Engineering Resources, Environmental Health, Industrial Hygiene, Tuberculosis, Venereal Diseases, Chronic Diseases, Communicable Disease Center, Dental Public Health, and the National Office of Vital Statistics.

The Division of States Grants was established in 1949 to recommend and to put into practice uniform policies and procedures for all grants-in-aid operations of the Public Health Service. This Division centralizes the administration of grants to the states and assures the maximum of efficiency and integration. These grants-in-aid are administered by the Public Health Service and in 1954 amounted to \$24,000,000. This included \$10,100,000 for general health work, \$3,500,000 for venereal



disease control, \$4,300,000 for tuberculosis control, \$2,300,000 for mental health services, \$2,200,000 for cancer control and \$1,100,000 for heart disease. These grants permitted further expansion of state and local health services and also made possible the training of large numbers of public health personnel. Under the stimulus of these grants nearly all states are in the process of expanding their mental health, dental health and cancer control services.

The National Office of Vital Statistics is a source of official data on births, deaths, marriage and divorce in the United States. It also issues the official tables of life expectancy and maintains the birth registration and death registration areas. This Division also gives consultation to the states in matters pertaining to vital records and statistics and in working with other organizations carries on studies in special health statistics and demography. The Division also represents the United States in international planning to improve the world system of birth and death registration and vital statistics.

The Division of Public Health Education provides assistance to states, voluntary agencies, educational groups and community agencies in the development of health education programs.

The Industrial Hygiene Division carries on a program of research and provides a consultation service to states and local communities in the development of adequate industrial hygiene programs. Upon request, the Division carries on detailed studies of specific industrial hazards.

The Division of Environmental Health carries on extensive studies and provides consultation to state and local health departments in the broad aspects of environmental sanitation, including water supply, sewage disposal, milk sanitation, the hygiene of housing, and other environmental problems. The Division administers the provisions of the Water Pollution Control Act of 1948 and has established a program of study of the water pollution problems in the major river basin systems of the United States. Under the direction of this Division is the Environmental Health Center at Cincinnati, Ohio, which is designed to coordinate all laboratory and field research in the general field of environmental sanitation.

The Communicable Disease Center with its main operation in Atlanta, Georgia, is a relatively recent development in the Public Health Service. It is a field research and training center providing consultation to the states on all problems in communicable disease control and provides a unique training program for personnel from local and state health departments. The special fields of interest, both from the standpoint of research and training, include epidemiology, malaria control, murine typhus control, rabies control and the broad field of gastro-intestinal infections, particularly the role played by the fly in the transmission of various diseases. The laboratory services provided by the Communicable Disease Center are available to state and local health services. The Center has set up uniform procedures for the performance of diagnostic tests and has provided training for laboratory technicians and public health workers in general. During the fiscal year 1949 more than 1,500 trainees were enrolled in courses offered by the Center. The students who came to the Center for training were for the most part from state and local health departments but 124 came from 37 foreign countries.

It is generally recognized that chronic illness is becoming increasingly important in the United States. In addition to the programs of research and training in the specific fields of cancer, heart disease, and mental and nervous diseases, the

Public Health Service has established a Division of Chronic Diseases. The purpose of this Division is to detect chronic illness in the earliest stages in order that prompt treatment may be given to effect a reduction in fatality where possible. One of the important functions of this Division is to cooperate with state and local health departments to develop methods for the early detection of the chronic illnesses. The work of this Division is closely coordinated with the work of the Division of Tuberculosis.

## THE CHILDREN'S BUREAU

A second major health agency in the United States is the Children's Bureau. This agency was first organized in the Department of Labor in 1912. The functions prescribed for the Children's Bureau in the Act creating it specified that the Bureau was to investigate and report upon all matters pertaining to the welfare of children and child life. For approximately a decade the Children's Bureau confined its activities to research and propaganda in matters affecting mothers and children. In 1921, passage of the Shepard-Towner Act provided subsidies for distribution to the states for the promotion of maternal and child health work. The administration of the Act was assigned to the Children's Bureau; under its provisions, the Bureau succeeded in securing the establishment of units of child hygiene activities in many states which had previously been without them. This greatly increased public interest in the subject. With the expiration of this Act in 1929, the functions of the Bureau were sharply curtailed, but with the passage of the Social Security Act in 1935, administration of funds appropriated for distribution to the states as grants-in-aid for the promotion of the health of mothers and children was again given to the Children's Bureau.

This Bureau serves as a center for the development of standards of care and protection for children in the United States and for the study of all phases of child life, including both the physical and mental health of children and the social and economic factors that affect their well being.

In July, 1946, the Children's Bureau was transferred to the Federal Security Agency from the Department of Labor and became a part of the Social Security Administration. The defined functions of the Children's Bureau are: (1) to investigate and report upon all matters pertaining to the welfare of children and child life; (2) to administer the program of grants-in-aid to the states for maternal and child health and for crippled children, under the provisions of Title 5, Parts 1, 2 and 3, of the Social Security Act; and (3) to cooperate with other American republics under the program of the interdepartmental committee on scientific and cultural cooperation.

Organizationally, the work of all divisions of the Children's Bureau is coordinated by the office of the Chief. This office is supported by numerous advisory and planning commissions and boards. The Bureau receives valuable help from standing advisory committees in preparing its publications on child care and in setting policies for grants-in-aid programs and in gathering statistics. Other committees assist in the development of standards for services for children, planning research, and determining how well needs are met and how services can be extended and public understanding increased. From time to time, conferences are called to discuss special problems in the various fields of service for children.



The Children's Bureau makes available to national, states and local organizations and agencies, its publications and information service to help them in their programs for children and youth. These organizations and agencies include those that promote measures for the improvement of child health, professional associations, child-placing agencies and other agencies giving various kinds of care and service for children. The Bureau is divided into four major subdivisions: the Division of Research, the Division of Reports, the Division of Health Services, and the Division of Social Services.

**The Division of Research.** The Division of Research conducts research on the physical, social and emotional growth and development of children, and on the needs for methods of extending or improving programs for services to children. It develops standards growing out of research, provides service on research aspects of demonstrations and special projects under grants-in-aid programs, and conducts a clearing house for current research in child life for the use of research workers. It provides statistical service to the Bureau and prepares bulletins and leaflets on child care in cooperation with the Division of Reports. It also provides technical information and consultation within the areas of the work of the Division.

**The Division of Reports.** The Division of Reports furnishes informational service to the press and radio, prepares visual media and publishes popular materials on research and administrative programs of the Bureau. It also provides consultation service in writing, designing and distributing of materials for professional and lay audiences; it prepares editorial reviews and publication of technical materials. In addition, it provides advisory services to state agencies on information services interpreting child health and child welfare programs.

**The Division of Social Services.** This Division develops policies and recommendations for social services to children, including case work with children in their own homes, care in foster homes, institutions or day-care centers, and adoption and guardianship. It administers grants to state welfare agencies for child welfare services and provides, through central and regional offices, advisory services to public and voluntary agencies and to others on standards, methods, and organization of state and community services, and on laws and their administration for the care and treatment of children who are dependent, neglected or delinquent.

**The Division of Health Services.** The Division of Health Services develops policies and recommendations for health services for mothers and children. It administers grants-in-aid to state agencies for maternal and child health services, and services for crippled children, including the location, diagnosis and treatment of children who are crippled or suffering from conditions which may lead to crippling. It provides, through central and regional offices, advisory services to public and voluntary agencies and to others on technical and administrative aspects of medical care and health services for mothers and children. The Division also provides advisory services on administrative organization and methods, and consultation in specialized medical and related fields, such as pediatrics, obstetrics, orthopedics, cardiology, nursing, dentistry, hospital administration, physical therapy, medical social work and nutrition.

The Division of Health Services is divided into two major subdivisions. The Field Operations Branch is directly concerned with the administration of maternal and child health and crippled children's grants-in-aid to the states, supervision of

the Children's Bureau regional staff, and review of the state plans, budgets and methods of apportioning the funds allocated to states. Each of the eight regional offices has a medical director and, if fully staffed, includes consultants in administrative methods, social work, nursing and nutrition. Individually or as a team, regional consultants visit each state health agency and crippled children's agency, conferring with directors and staff members and advising on the operation of state programs, standards of services and ways of extending and improving health services for mothers and children.

Under the grants-in-aid program assistance is given to state public health agencies to enable them to extend and improve maternal and child health services, especially in rural areas and in areas suffering from severe economic distress. The Social Security Act, as amended in 1946, authorizes an annual appropriation of \$11,000,000.00 for this purpose. The program is in operation in all of the states, the District of Columbia, Alaska, Hawaii, Puerto Rico and the Virgin Islands. The state health department through its division or bureau of maternal and child health allots federal and state funds to county or local health departments for maternal and child health services, and provides consultation services for supervisors in the medical, dental, nursing, medical-social, nutrition and health education phases of the maternal and child health program, and to hospital administrators and hospital staffs on the improvement of services for mothers and children. Postgraduate courses in obstetrics and pediatrics are held for practicing physicians, and institutes and training courses are held for public health nurses and other health workers. The health needs of mothers and children are studied and, with the help of professional and citizens groups, efforts are made to mobilize the resources needed to meet these needs. Locally, the maternal and child health program is carried on by the county or city agency under the direction of the health officer.

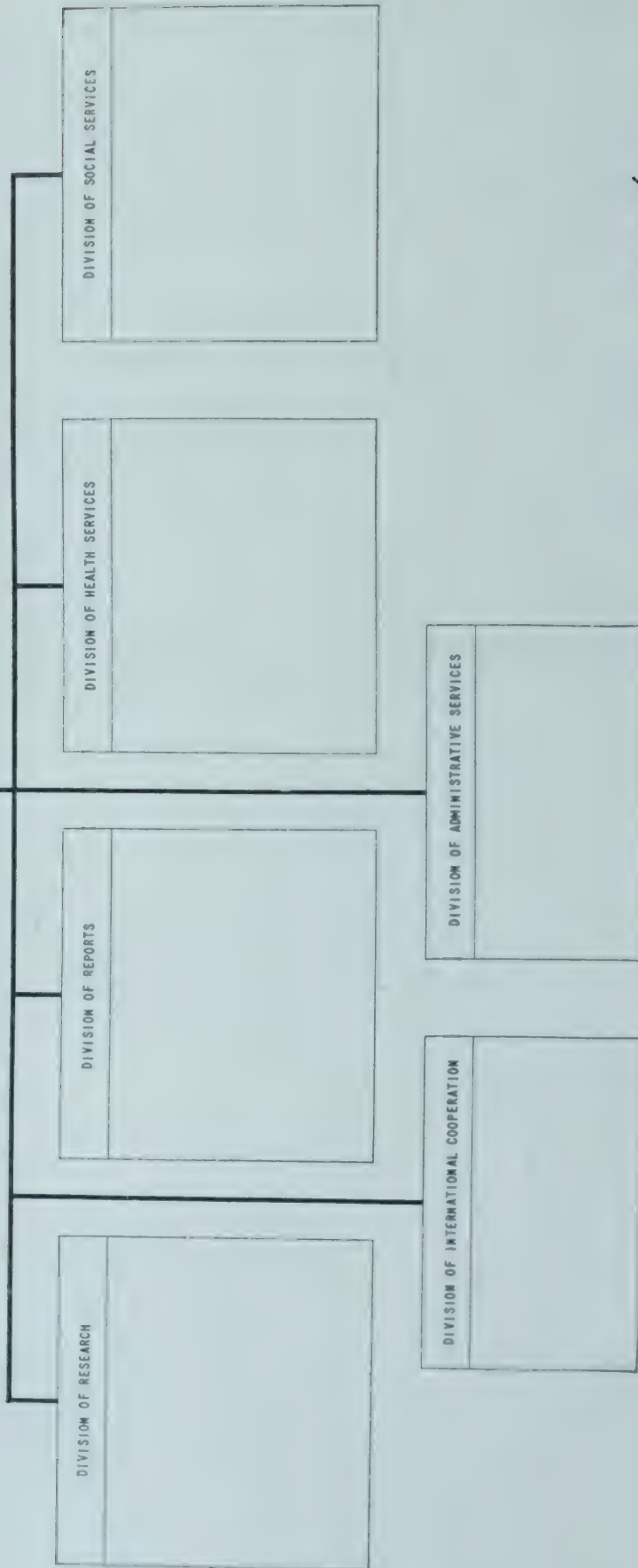
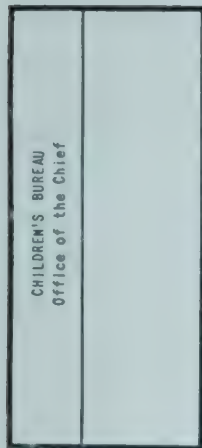
Similar health services for school children are conducted in cooperation with schools and, in a limited number of areas, home delivery nursing service is provided at the request of the attending physician. Supervision is given to midwives in some counties, and nurse midwives are provided to train and supervise and give midwifery service. In a few states medical care for mothers at delivery and care for sick children is provided.

Programs for the care of the prematurely born infants are being developed in most of the states. These programs include one or more of the following services: educational courses on the care of premature infants for physicians and nurses; purchase of incubators for loan to hospitals or for home use; licensing and supervision in maternity hospitals and newborn or premature nurseries; ambulance service for transferring premature infants to suitable hospitals; medical and hospital care in a hospital center having specialty facilities; and furnishing trained personnel for care of premature infants. Adequate public health nursing programs for home follow-up of prematurely born infants are also included.

With grants-in-aid assistance many states are expanding sight and hearing conservation programs which vary from programs of testing sight and hearing to complete remedial service, including purchase of glasses or hearing aids. Programs to prevent dental decay by the application of sodium fluoride to the teeth of school and preschool children are also being developed extensively.

Funds from federal, state and local sources are not yet sufficient to make the many health services needed for women and children available in all counties and





*M. L. Givens*

Deputy Commissioner for Social Security

Fig. 47-2. Organizational chart—Department of Health, Education and Welfare, Social Security Administration, Children's Bureau

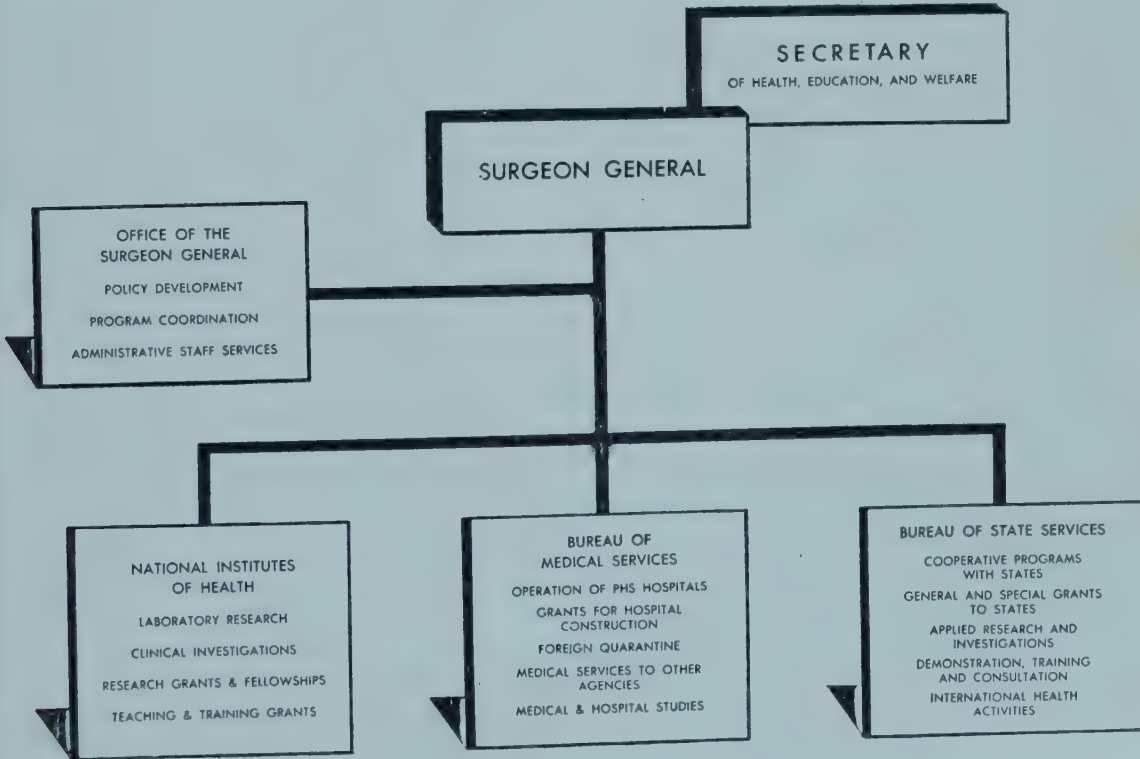
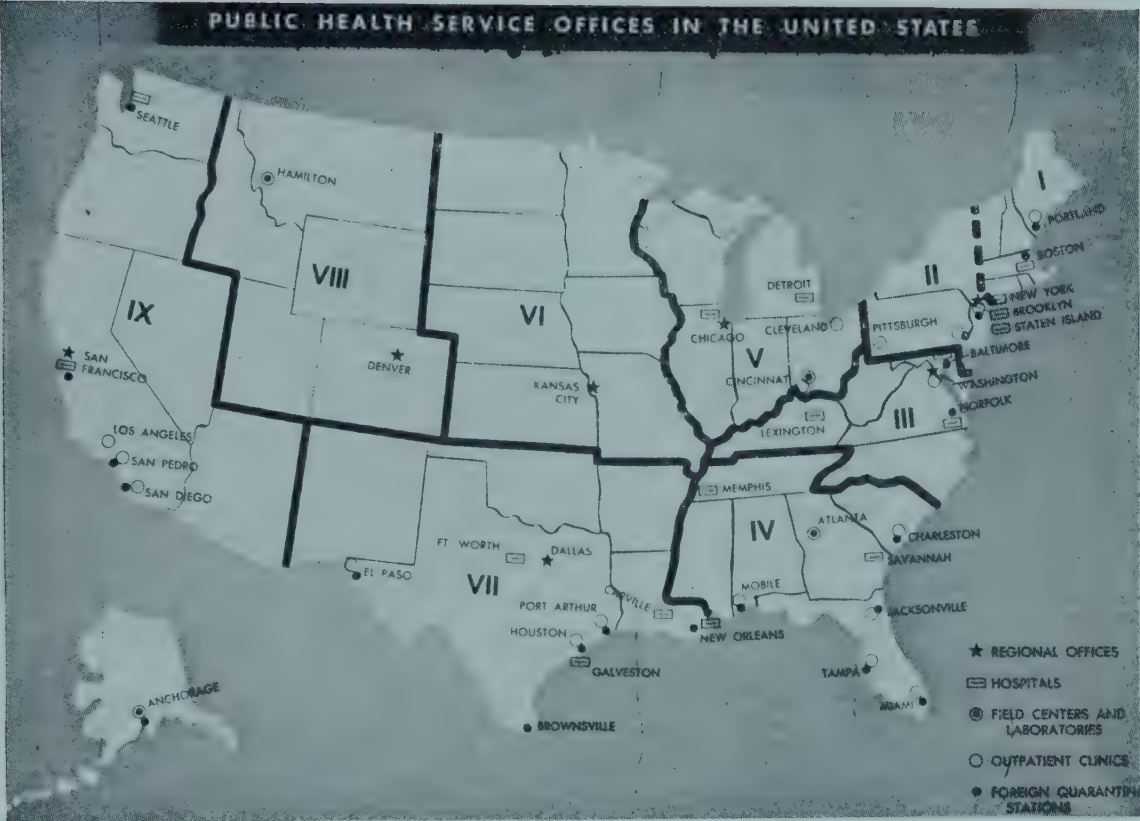


Fig. 47-3. Organizational chart—Department of Health, Education and Welfare, Public Health Service.



communities. Even where programs are started there are not always enough workers to meet the need. There is a marked shortage of the professional personnel required to carry out maternal and child health programs. With the increased birth rate, state and local health agencies are urged to create prenatal clinics and well-child conferences and public health nursing services for mothers and children so that those in need of such services will be able to secure them.

The Program Planning Branch of the Division of Health Services provides advisory services to regional offices, and public and voluntary agencies in specialized fields, including pediatrics, orthopedics, obstetrics, cardiology, psychiatry, nursing, nutrition, physical therapy, administrative methods, medical social work and hospital administration. It provides technical guidance and leadership to regional medical directors, and consults with educational institutions and national agencies on the promotion of training opportunities in the professional fields relating to maternal and child health. This branch also plans and formulates recommendations for the development of programs for maternal and child health services and services for crippled children, and prepares technical reports, articles and educational material in these fields.

**SERVICES FOR CRIPPLED CHILDREN.** Grants are made from the Children's Bureau to state crippled children's agencies to enable the states to extend and improve services for crippled children. The Social Security Act, as amended in 1946, authorized an annual appropriation of \$7,500,000.00 for this purpose. The program is in operation in all of the states except one (Arizona), in the District of Columbia, Alaska, Hawaii, Puerto Rico and the Virgin Islands. State plans are reviewed each year by the Division of Health Services for approval by the Chief of the Children's Bureau. Grants under Title 5, Part 2, are used to provide medical, surgical, corrective and other services, and care for children who are crippled or who are suffering from conditions that lead to crippling, and to provide facilities for diagnosis, hospitalization and after-care of such children. Twenty-six state agencies for crippled children include special programs for the care of children suffering from rheumatic fever or heart disease. Several states are developing programs for the diagnosis and treatment of children with hearing defects.

Approximately 175,000 crippled children received service in 1949 under state plans approved by the Children's Bureau. The state agencies responsible for administering services for crippled children in 1950 were as follows: 32 health departments, 10 public welfare departments, 4 crippled children's commissions, 3 departments of education, and 4 state university medical schools or hospitals. Each state agency for crippled children maintains a register. Approximately 510,000 crippled children were registered on December 31, 1948. Diagnosis and some treatment is provided in clinics held for crippled children in permanent clinic centers or at intervals in itinerant clinics. When hospitalization and medical and surgical care are needed, the state agency assumes responsibility for arranging care at a hospital as near as possible to the child's home and for obtaining the services of a physician or surgeon. Plans are made for the child's subsequent care in a convalescent home or in his own home and for medical and public health nursing supervision and physical therapy to complete his physical restoration. Medical social service is provided also to aid the child in adjusting at home, at school and in neighborhood activities. Children for whom such opportunities are appropriate are referred to vocational training when they reach 16 years of age.

## THE PROVINCIAL OR STATE HEALTH ORGANIZATION

Most national governments are divided into a number of political subdivisions having varying degrees of political autonomy. The major subdivisions of national government are usually called provinces, departments, or, as in the United States, state governments. These major subdivisions are in turn subdivided into local governmental authorities, municipalities, communes, counties, etc. In different countries the relationship of national government to the various subdivisions differs greatly in health supervision as in other governmental activities. In strongly centralized governments the primary responsibility for health activities is vested in the national government. In others, the primary responsibility is in the local subdivision. The general trend toward the centering of the taxing power in the central or national government has tended to transfer greater and greater control of health services to the central or national governments.

In the United States, as previously pointed out, the state government is the sovereign power and in health matters, as in other governmental activity, the national and local governments possess only those powers delegated to them by the state. The state constitution usually defines in broad general terms the responsibility of state government for the maintenance of the general health and welfare of the citizens. Acts of the state legislature define in more or less detail the organization and functioning of the state health department. Health laws in the 48 states differ greatly. In some, there has been extensive legislation specifying in great detail the health activities to be carried out and the organization of the health department. In others, only broad principles are laid down and special laws are enacted as urgent needs are recognized. A few states have detailed public health laws, codified and classified to form a well-planned legal basis for health activities; far more have scattered enactments to meet specific needs, which are imperfectly related one to another. In all of the 48 states there is some provision for a board of health or a comparable body whose functions are usually primarily advisory and legislative in nature. The size and composition of the board is usually specified in the law. The number of members varies from three or four to the total membership of the state medical society in one state. The qualifications for membership range from that of an intelligent public-spirited citizen to the very specific representation of professional groups interested in the promotion of health. The most frequent requirement is that a majority represent the medical profession. The members of the board of health are usually appointed by the governor for a fixed term of years; not infrequently the terms of the various members are staggered to provide for continuity in action. In addition to advisory functions, in most states the board is charged with certain legislative duties. The enactment of sanitary code regulations



declared to have the force and effect of law is a common responsibility. The validity of such legislative action depends upon the specific delegation of this power by action of the state legislature. In some states the board of health nominates or appoints the health officer. More frequently the health officer is appointed by the governor with the advice of the board. In some states the board establishes the qualifications not only of the health officer but of other professional personnel within the department. Actual appointment of the state health officer in these instances is by the governor and the appointment of other personnel in the department is the responsibility of its executive officer under civil service or merit system regulations.

In general, experience seems to indicate that the most effective state boards of health are those consisting of from 7 to 12 members appointed by the governor for periods of from four to six years with staggered terms so that there is continuity in action as a result of the maintenance of an experienced group. The combination of advisory and legislative function has proved to be very effective but the inclusion of any administrative responsibility has quite generally been found to be undesirable.

The state health officer is usually appointed by the governor as a member of his cabinet and is the head of a major department of the state government. His qualifications, duties and compensation are usually specified by state law. His term of office may be specified or he may serve at the pleasure of the governor. Efforts have been made to separate the health department from politics by the establishment of a term of office for the health officer that does not necessarily coincide with that of the term of the governor. For example, a six-year term for the health officer and a four-year term for the governor. In a few states the position of the health officer has by tradition become nonpolitical and where possible this seems to be a more adequate safeguard than the establishment of a fixed term.

### STATE HEALTH SERVICES

Historically, the states of the United States have been slow to recognize their responsibility for the health of the citizens. One of the first movements for the development of a state health department was in Massachusetts, where in 1850 abortive attempts were made to establish a state board of health and to develop a state health department. This was short lived and the first permanent state health organization was established in that state in 1869. This is generally accepted as the first permanent state health organization in the United States. Other states followed soon after this, and, stimulated by the great epidemics of cholera and yellow fever which prevailed during the 1870's, a considerable number of state health departments and state boards of health were established. The increasing recognition of the need for health services resulted in the establishment of some 18 state boards of health and state health departments within the decade. By the turn of the century, 38 states had developed some form of state health organization with state boards of health and at least rudimentary state health departments. By 1913, every state and territory in the Union had one.

The early boards of health consisted of groups of physicians who served without pay and who were authorized only to make investigations and to report their

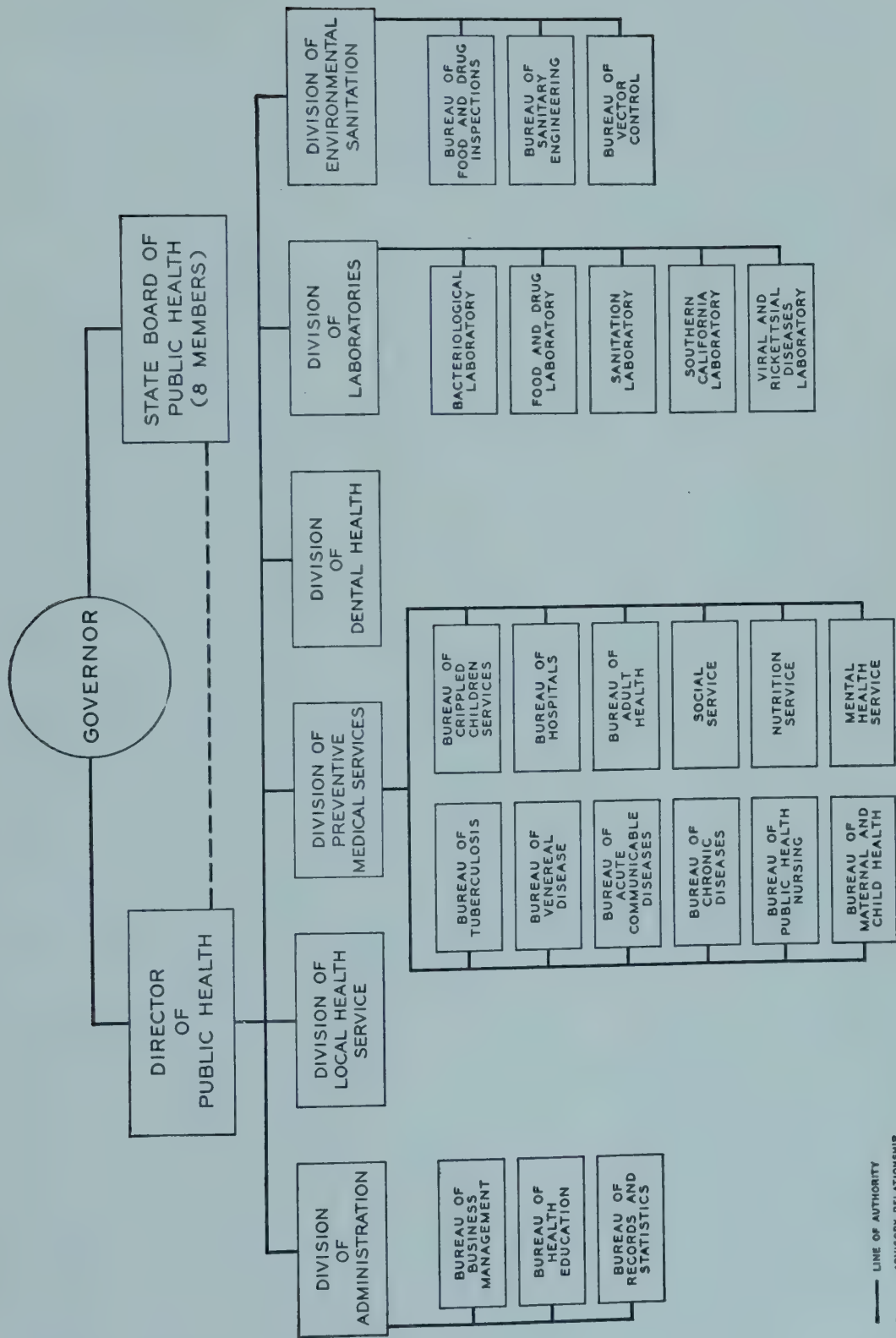


Fig. 48-1. State of California Department of Public Health.



findings and recommendations to the governor or the legislature of the state. At about the beginning of the twentieth century, the more progressive states began to develop more adequate staffs and to extend the programs for the prevention of disease and disability. In the early development of the public health movement in the states, control of communicable diseases was the principal objective. This required the provision of laboratory services for diagnosis. The next step in state health services was in the field of environmental sanitation, in the development of laws and regulations pertaining to water supplies, stream pollution, and sewage disposal. Sanitary engineering became one of the most important fields of state health department activity.

From the very beginning, state boards of health and state health departments were called upon by municipal and local officials for assistance in the control of epidemics. With the growth of interest in all health matters, these calls became more frequent and urgent. To meet these needs, the state boards of health began to provide field services for the diagnosis of doubtful cases of communicable disease and for the study and control of epidemics. This need of the small communities and rural areas for technical services has had a considerable influence on the development of the state health organization. It has been their task to work out plans and an organization whereby these essential services could be made available to smaller communities and to rural areas. One of the most important branches of the modern health department is the division of local health administration. In some states, an attempt has been made to provide local health service as a direct extension of the state health department's activities through the organization of health districts. In other states, assistance has been given to the development of local health services through a program of grants-in-aid or state-aid programs. In the latter system, financial support has been given to the development of local health services by matching local expenditures under various formulas with a proportion of the cost of maintaining local health services, provided they met basic standards of the state health organization.

The organization of most state health departments is on a divisional or bureau basis, providing certain standard services in the specialized fields. The usual subdivisions of a state health department are as follows:

1. Vital statistics.
2. Environmental sanitation.
3. Public health laboratory services.
4. Communicable disease control, including the acute communicable diseases, venereal diseases and tuberculosis.
5. Maternal and child health which may include services for the physically disabled.
6. Public health nursing.
7. Health education.
8. Industrial hygiene, although this is not infrequently included in environmental sanitation.
9. Mental hygiene.
10. Local health services.

There is considerable variation in the organizational pattern of various state health departments but these basic minimal services are now considered as essential to any state health activity. The minimum functions of a state health organization as defined by standards of the American Public Health Association are:

1. The study of state health problems and planning for their solution.
2. Coordination and technical supervision of local health activities.
3. Financial aid to local health departments.
4. The enactment of sanitary regulations applicable in local health programs.
5. The establishment of minimal standards for local health work.
6. The maintenance of central and branch laboratory services, including diagnostic, sanitary, chemical, biological, and research activities.
7. The collection, tabulation and analysis of vital statistics.
8. The collection and distribution of information concerning preventable disease.
9. The maintenance of a safe quality of water and the control of waste disposal.
10. Establishment and maintenance of minimal standards of milk sanitation.
11. Provision of services to aid industry in the control of occupational hazards.
12. The establishment of qualifications for health personnel.
13. Formulation of plans in cooperation with other organizations for meeting all health needs.

There is considerable variation in the pattern and the lines of authority within states. There is generally a reasonably straight line of authority from the governor to the executive officer or health commissioner of the state, with the state board of health serving for the most part as an advisory body and a quasi-legislative body. The state health officer is the administrative head of the organization in almost all states and he is assisted by various deputies or assistant commissioners. In order to simplify administration, there is a growing tendency to reduce the number of bureau or division heads reporting directly to the commissioner. There is an equal tendency to increase the number of professional or technical advisory boards and councils serving in a purely advisory capacity to the executive officer of the state health organization. The major subdivisions, while they vary in different states, show certain definite similarities in that general administrative services or the management services of the health department are grouped together and are more or less directly related to the executive officer's line of supervision. In addition to the major subdivision of administration there is usually a grouping of more or less related activities into the following major bureaus or divisions: environmental sanitation, medical services, and local health administration. This type of organization is in contrast to the rather diffuse pattern current one or two decades ago, when each specific activity of the health department had a separate divisional status with a specialist reporting directly to the executive officer in each special activity of the health department. With the expansion of the program of the official health agencies, no one person could conceivably be an expert in all phases of the activities, and the need for technical advice has been met by the establishment of a constantly increasing number of advisory committees and special consultants to the executive officer.

### THE BUREAU OF GENERAL ADMINISTRATION

The division of general administration is usually under the more or less direct supervision of the executive officer. This is true not only because the executive officer of the department is legally responsible for the administration of large sums of money but under certain state laws, the health officer, commissioner, or executive officer of the health department is personally designated as the responsible agent for many of the activities of the state health organization. There may be specific provision in the law for personal exemption from responsibility provided he oper-



ates within generally accepted standards of practice in the field of public health, and the health officer is not infrequently given by the law extensive emergency powers for the protection of the public health. The health officer is usually charged with the enforcement of the public health law of the state and the sanitary code as enacted by the public health council or state board of health. In some states, he is given specific police powers and in certain instances is deputized by the police authority to carry out certain police functions. In order to carry out the many and varied functions of the administrative office, certain subdivisions have been set up with specially qualified personnel to carry out these functions under the direction of the state health officer. While the division of responsibility varies in different health departments, the following are most frequently found: (1) a legal division; (2) a licensing or permit division; (3) a division of budget or audit and accounts; (4) a division of personnel management; (5) a division of public relations; and, depending upon the size or complexity of the organization, additional divisions.

**The Legal Division.** The legal division is responsible for drafting necessary legislation and for maintaining liaison with the legislative branch of the state government in order to advise and assist in the drafting, introduction, and support of sound public health measures. With rapidly developing programs of public health in many states, this is an important function of the state health department and may require the skill of individuals not only trained in the law but with a comprehensive understanding of public health problems.

Inasmuch as the state board of health has in most states a specific legislative function in the drafting of the sanitary code and the maintenance of sound regulations, the legal division has considerable responsibility in the development of sanitary code regulations, interpreting the legal implications, and the drafting of the regulations in a clear and concise form which will stand up under court scrutiny. In certain situations, the health department must take legal action to enforce sanitary code or other regulations of the department and not infrequently court action is taken in the name of the state health officer or in the name of the state board of health. In these instances, competent representation in court is essential either by a legally trained member of the staff or through the state attorney general's office.

With the development in many states of more and more complicated civil service regulations and procedures, legal advice is not infrequently needed in carrying out necessary disciplinary action, or in the determination of policy; with a competent, legally trained member of the staff, such advice can be most readily provided.

**Licensing or Permit Division.** Under the public health law in many states, the department of health is charged with the responsibility of inspection, approval, and licensing of a great many different types of business or commercial operations. Many state laws require the inspection and licensing of dairies, milk plants, restaurants, beauty parlors, barber shops, etc. In such instances, there are specific regulations as to the operation of such establishments and an inspection service must be provided. Not infrequently, rather considerable fees are charged in connection with the licensing of these establishments and, in some instances, a significant proportion of the financial support of the health department activities comes from this source. In order efficiently to operate such a program of licensing, a well-organized administrative unit is required to maintain close liaison with the inspection

services and the enforcement of sound sanitary regulations. In certain states, the approval and licensing of public health laboratories is also included within the responsibility of this division.

In recent years, there has been a growing tendency to place upon the state health department responsibility for maintaining certain standards for technical operators in fields which may have a direct or indirect bearing upon public health. In many states certain technicians are subject to regulations of and are licensed by the state department of health. These include laboratory technicians, x-ray technicians, midwives, oxygen-therapy technicians, exterminators, and, in some states, plumbers. In order adequately to carry out this function, boards may be created to examine applicants for licensure in these fields, to determine technical competence, and to maintain standards.

**The Division of Budget or Audit and Accounts.** As the responsibility of state health departments has increased, there has been more and more need for an efficient business management unit within the department. When it is realized that some state health departments at the present time operate on a budget of 20 to 30 million dollars per year, it is obviously necessary that an efficient system of business management be established. The mere matter of bookkeeping of departmental expenditures in larger state health departments becomes a major undertaking and requires competent personnel. This may include the purchase of considerable volumes of equipment and supplies with the possibility of great savings if efficiently conducted. In those states in which there is provision for state aid, either through state funds or through state and federal funds allocated to the state, there may be the problems of audit of accounts of local health services in order that expenditures of the local health department are in accordance with approved budgets. There are very few states that do not have financial relationships with local health services within the state at the present time and the maintenance of an adequate system of accounts in these joint programs is essential. The preparation of an annual budget for a large health department is a rather complicated undertaking and requires special skills. Moreover, the operation of a modern health department under a line item budget requires extensive dealings with the budget director to maintain an efficient operating department.

**The Division of Personnel Management.** In most state health departments, the personnel is sufficient to require the development of definite policies and the maintenance of an efficient service. This division should also be under the direct supervision of the executive officer of the state health department. It should serve the functions of recruitment and training of staff to maintain an efficient organization, and its responsibilities in this regard may be rather extensive. There has been increasing recognition of the great importance of the recruitment of professional staff and this has become an important activity in some health departments. In connection with recruitment, particularly of medical personnel, there is a need for the establishment of a training program, including academic and field training, to maintain an adequate staff. Impetus has been given to the development of these training programs as a result of the establishment of a specialty board in public health which requires a basic training that includes academic and approved field training. A number of state health departments have within recent years established



well-organized and supervised training programs to provide an adequate supply of trained personnel.

Another function of the personnel management division is the maintenance of personnel records and service rating programs. Under most merit systems, there is a necessity for evaluation of the quality of the work of employees of the department and efficiency rating forms have been developed in an attempt to measure accurately the efficiency of individuals employed by the department. These efficiency ratings present obvious difficulties in evaluating the services of an individual employee, but in competent hands may be of great value in maintaining a high quality of service. Another function of the division may be the development of inservice training programs for all types of employees. Many health departments rely rather largely upon part-time staff for the clinical operations of the department, recruiting clinic physicians from the general practitioner group within the state. In this group, inservice training is particularly important to maintain a high quality of preventive medical services in the clinics, and is also of vital importance in the development of new programs providing staff members with opportunity to obtain technical skills in the specialty fields that may be newly undertaken.

In most state health departments, merit system programs have been established and employment of personnel is through the civil service commission of the state. The personnel officer has an important responsibility in the maintenance of satisfactory relationships with the civil service commission, assisting in the development of satisfactory qualifications and duties for employees at various grades. This office may also assist the civil service commission in the development of job analyses, appropriate salary gradings and an adequate examination procedure.

Under civil service laws primarily designed for the protection of the employee, constant diligence must be maintained by the personnel office to avoid the perpetuation of mediocrity. This can best be done through careful use of the probationary period which permits of the early elimination of inadequate personnel under a civil service system. The personnel office also can, through proper use of disciplinary measures provided within civil service laws, eliminate incompetence from the service but only by the employment of sound personnel practices.

Within recent years, a new personnel problem has developed in some state health departments with the unionization of certain types of personnel. It would seem doubtful that sound personnel practice would permit of the direct opposition to unionization of health department employees but sound labor practices are necessary in order to avoid difficulties under these circumstances. One method that has been found to be effective in dealing with these problems is to set up grievance committees within the personnel division to provide for adequate hearings on all complaints that may be made by employees.

Another responsibility of the personnel division might well be the maintenance of staff morale. The efficient operation of any organization, whether it be a business firm or a health department, depends upon good staff morale. In maintaining staff morale, nothing will take the place of adequate salaries, reasonable hours of work, satisfactory holiday schedules, sick leave, and vacation time, but much can be done to improve staff morale under otherwise adequate conditions. One of the most important factors in maintaining good morale in a health department staff

is the provision of a satisfactory method of communication within the department. A clear understanding of responsibilities, methods of procedure, and lines of authority may be established through clearly worded rules and regulations of the department and manuals of operation available to the entire staff. Adequate lines of communication avoid misunderstanding and the feeling of having been left out of the councils of state. Another method of maintaining adequate understanding of the basic objectives of the health department may be the staff conference in which all members of the staff are brought together once a year or perhaps more frequently for a general discussion of problems common to all or the majority of the staff of the department. In certain circumstances, social events and sports may have their part to play in the maintaining of a high level of morale in the health department staff.

**The Public Relations Division.** The effectiveness of any health department's activities can be greatly increased by maintaining sound public relations. Moreover, with sound public relations, an effective job of health education is much more apt to be attainable. One of the most important channels for public relations is the press. Health is news, whether it is a report of a serious epidemic or a new record low in infant mortality. Many instances could be cited in which a newspaper campaign for improved health facilities has been the deciding factor in obtaining adequate appropriations. Relationships with the press must be maintained with a fine degree of diplomacy. The health officer who makes use of the press to bludgeon his appropriating bodies into providing adequate facilities may find himself in difficulty. On the other hand, a sound policy of giving out information impartially to all of the newspapers and reporters involved can, with few exceptions, develop a perfectly satisfactory relationship with the press. The radio and television offer opportunities for exploitation in the health field. Unfortunately, these have limitations in that the maintenance of a high quality of program on either radio or television requires highly skilled individuals and tremendous amounts of time and energy. Depending upon the technical skills that are available, these media of communication can be used to advantage.

Another extremely important field of activity is the relationship of the health department to the various civic organizations, such as the women's clubs, citizens' unions, health councils, and other community organizations. Many of these community organizations, particularly the voluntary health agencies, have a direct interest in health and they can be a tremendous force in the community for the improvement of health services and the support of a sound health program. The health officer and his division of health education should make use of the interests that are already developed in these organizations and, where they are not well organized, can well devote considerable energy to community organization in order to develop this interest and support.

No health department can afford to neglect the cultivation of satisfactory professional relationships, particularly with the state and county medical societies, to establish understanding of the health department's programs, to make use of these facilities in cooperative educational projects, and to obtain the advantage of competent technical advice.



## BUREAU OF ENVIRONMENTAL SANITATION

One of the major subdivisions of any health department is the division of environmental sanitation or the division of sanitary engineering. It has long been recognized that certain environmental controls are of tremendous importance in the protection of the public health. One of the earliest environmental factors to be recognized as capable of producing disease and disability was the public water supply. In the United States, elaborate measures, which have been outstanding in their accomplishments in the prevention of water-borne disease, have been provided for the safeguarding of public water supplies. In the final analysis, the health department is responsible for the procurement of safe water supplies and, in many instances, for the maintenance of an adequate supply. In the larger municipalities, rather elaborate provision has been made for the collection and distribution of water and this has been the responsibility of a division of government other than the health department. Nevertheless, the health department has a definite responsibility in almost every state to provide technical guidance in the selection of basic sources that will be free from contamination and to set up regulations to assure the continued sanitary quality of water that is to be used as a public supply. This involves the use of highly skilled sanitary engineers to determine the safety of the supply, the possibilities of contamination, and the adequacy of purification methods used. In the United States, most of the water supplies for urban communities are derived from surface sources and require complex purification processes, which may include filtration and chemical treatment. Certain safeguards are necessary to avoid the possibility of contamination within the distribution system. The state department of health must provide competent technical advisors in the development of treatment processes and of adequate and safe distribution systems. Having established an adequate source, method of treatment and distribution system, the health department still has the responsibility of supervising treatment in order to maintain a safe sanitary quality. To do this, supervision must be maintained throughout the processing of water and a system of sampling must be set up to determine the quality of the water at points of distribution. This also requires the maintenance of adequate laboratory facilities to determine the quality of the water.

The United States Public Health Service standards for water acceptable for interstate carriers provides a basic standard for water quality and also provides a very potent incentive to maintain the high quality of water in local communities. The threat of failure of approval of the water supply for interstate carrier use will sometimes bring about corrections otherwise difficult to obtain. Direct supervision of all public water supplies within a state is obviously beyond the possibilities of most state health departments. In order to be assured of a safe quality of water in all municipalities, the state health department may establish basic standards and a system of sampling in order to determine the compliance with these standards. Another method that has been used rather extensively is the specification of the qualifications of water-plant operators by the state health authority.

The safeguarding of private water supplies presents difficult problems both to the state and to the local health departments. Safe, private water supplies depend primarily upon education of the public, and many health departments have de-

veloped effective educational devices to assist the private property owner in procuring a safe supply for home use.

**Sewage Disposal.** Another major responsibility of the state health department is the development of safe methods of disposal of sewage, particularly from municipalities and from industries. Of primary concern in this field is the avoidance of stream pollution, either through utilization of the principle of dilution or through the treatment of sewage wastes prior to disposal in natural waterways. The first consideration must be the safeguarding of public water supplies from surface sources that might be polluted by municipal sewage disposal. Some state laws give the state health department broad powers and great authority to require the adequate treatment of sewage wastes. Another responsibility of the health authority is the requirement for disposal of human waste in such a way as not to produce a nuisance which might be of some health significance. In certain circumstances health hazards may be created by pollution of bathing beaches or areas from which seafood is harvested. In addition to these hazards from sewage disposal, the health department has increasingly concerned itself with the possibilities of local contamination through improper plumbing connections and construction. The important part played by cross connections in the contamination of municipal water supplies has been clearly recognized in the past two decades. Health departments have, therefore, established regulations for all new plumbing installations and as rapidly as possible are eliminating potential cross connections due to faulty plumbing. The problem of eliminating hazards from sewage disposal in private establishments is primarily one of the rural areas and suburban communities. Particularly in the southern part of the United States, there have been extensive programs of rural sanitation stimulating the construction of sanitary privies and septic tanks as a means of preventing the creation of nuisances, the spread of hookworm, and other helminthic diseases, and to reduce the prevalence of flies as a possibility in the transmission of disease. In rapidly developing areas around urban communities, extremely serious problems of sewage disposal have been created. These problems are met by the establishment of regulations as to the type of sewage disposal system that may be installed within these areas.

In some communities, the disposal of garbage and waste other than human waste is considered the responsibility of the health department. Although not specifically of health significance, the disposal of this type of waste may create a nuisance and the health department inevitably becomes involved. For this reason, sanitary code regulations require certain precautions in the disposal of garbage either through incineration, carefully controlled use of sanitary landfills, or, if garbage is to be fed to hogs, heat treatment which will assure the destruction of trichina.

See Chapter 41 for a technical discussion of sewage disposal.

**Milk Sanitation.** The protection of the milk supply of the community is a major function of a health department. The state health department establishes basic standards for the production, processing, and distribution of milk to assure a safe, sanitary quality. Local communities may establish regulations not inconsistent with the state regulations. Under modern methods of pasteurization and methods of testing for adequacy of pasteurization, there is no longer any excuse for the spread of infection through this medium. There is a growing tendency to



emphasize the requirement of pasteurization and the inspection of pasteurization equipment and procedures to assure safety in milk rather than extensive inspection on the producing farm. While dirty milk adequately pasteurized will not produce disease, it is generally agreed that citizens are entitled not only to a safe milk but to a clean milk and, on this basis, rather elaborate regulations have been established by most state health departments to assure a clean milk supply. Because of the confusion not infrequently created by conflicting regulations of municipalities having overlapping milk sheds, there has been a growing tendency to establish standard milk production codes not only within a state but between states. The United States Public Health Service Standard Milk Code has been accepted by an increasing number of states and will eventually, in all probability, provide for a relatively free interchange of milk throughout the United States. Regulations governing the processing of milk are of the greatest importance, particularly in large cities where tremendous quantities of milk are pooled and distributed. Great progress has been made in recent years in the development of efficient pasteurizing equipment which may be easily tested for efficiency, and, with the use of the phosphatase test, any defect in the pasteurizing process can be quickly detected. Constant vigilance is necessary to assure a safe milk supply for any community. Until quite recently, considerable attention has been paid to bacterial standards, butterfat content, and grading of market milk. There has been a growing tendency to discount the values of this type of grading and to require basic minimal standards in terms of cleanliness and bacterial counts and to consider only minimal butterfat content. From the public health standpoint, reasonably clean, adequately pasteurized milk with butterfat within normal limits is all that it seems reasonable to require. In rural communities where pasteurization is impracticable, elimination of tuberculosis and brucellosis from milking herds is imperative and precautions to avoid the use of milk from cows possibly suffering from mastitis is necessary. In private households and one-cow dairies, these are the only precautions that seem reasonable at the present time.

See Chapter 21 for a technical discussion of milk sanitation.

**Safeguarding of Food Supplies.** Regulations concerning the wholesale production and handling of food are usually prescribed in state sanitary codes. Responsibility for the inspection to enforce these regulations lies, for the most part, with the local health departments. In most states, the inspection of meat shipped in interstate commerce is primarily the responsibility of the Department of Agriculture of the Federal Government. Other local requirements may be set up for locally killed meat not destined for interstate shipment but here again, the inspection program is primarily a local health problem. The supervision of retail food establishments, particularly restaurants, is a joint responsibility of state and local health departments. Basic standards of cleanliness are established by state sanitary code regulations. In some states, rather detailed regulations concerning methods of dishwashing in public restaurants are prescribed. In a few states, a physical examination of food handlers is still required, although it has been rather effectively discredited. It is now pretty generally agreed that restaurant sanitation is most effectively handled through training courses for food handlers and the limited utilization of laboratory tests for the sterility of dishes.

See Section 4 for a technical discussion of food sanitation.

## THE BUREAU OF MEDICAL SERVICES

In the larger, and particularly in the more completely developed, state health departments there has been a tendency to group together those services which require medical activities as a basic part of the public health program. These bureaus or divisions usually include services for the control of the acute communicable diseases, tuberculosis, and venereal diseases; programs for maternal and child health; services for the physically handicapped, for dental hygiene and mental hygiene; programs for adult health, which usually include industrial health; and chronic disease services, including a program of control of cancer, heart disease and diabetes. They may or may not include subdivisions for social service and nutrition. Under such a bureau there is usually some administrative subdivision for the specific specialty programs of the department.

**Organization for the Control of the Communicable Diseases.** The measures employed by the health department in attempting to control the spread of communicable diseases are varied, differing according to the nature of the infectious agent causing a particular disease and the mechanism by which it is spread through the population. The oldest of all such measures is that of isolation. If it is believed that a particular disease spreads from the person suffering from it to those well persons who come in contact with him, the most obvious and natural procedure is to attempt to reduce the amount of this contact. This is usually done by isolating the sick person and restricting access to him to the smallest possible number of persons. The extension of this idea of isolation led to the restriction of travel and commerce between areas affected with communicable diseases and those in which the disease had not yet appeared. The enforcement of quarantine has in the past led to great hardship and suffering to helpless individuals and to costly and sometimes paralyzing interference with commerce and travel. Preventing the spread of disease by isolation or quarantine has not in practice proved to be as simple as it would appear. The recognizable case is seldom the sole source of infection and contact with him is not necessarily the means by which the disease is spread. Even under the most favorable circumstances the existence of a disease cannot usually be recognized until the patient has already had some, if not abundant, opportunity to spread infection. In some of the serious infectious diseases isolation is recommended primarily to protect the patient from possible secondary infections.

Another historic procedure for the prevention of the communicable diseases is that of disinfection. From earliest times, the effects, and frequently the dwelling, of the infected person have been washed, fumigated with aromatic or evil smelling substances, or even burned for the purpose of destroying any infectious substance that might cling to them. When it was demonstrated that many diseases are caused by living agents and that these agents can be destroyed by certain chemical substances, these ancient practices were strengthened in the minds of physicians and the population alike. This led to the use of such substances as formaldehyde, carbolic acid and bichloride of mercury for the disinfection or fumigation of persons and premises. It has been amply demonstrated that most infectious agents do not long survive outside the human body and that disinfection at the bedside of the actual secretions and excretions of the patient followed by the use of soap and water and otherwise normal cleanliness is of greater value than the elaborate pro-



cedures formerly employed. At the present time, therefore, disinfection is a simple procedure used only where study and experiment have indicated its value.

The demonstration by Jenner at the end of the eighteenth century that an individual might be completely protected against smallpox by inoculation with a mild and harmless cowpox vaccine made it possible for the first time in human history to control one of the great plagues. With advancing knowledge of the nature of the agents causing the infectious diseases, it has been possible to develop means of protection against a number of other diseases, and specific immunization has taken its place as one of the most important procedures in the control of the communicable diseases.

Many diseases are spread by arthropod vectors. These diseases may be controlled by measures that prevent the breeding of the specific insect vector concerned, destroy adult insects and protect human beings against their bites. Certain diseases are spread by contaminated food or drink, particularly water or milk. These diseases, principally those of the alimentary tract, may be prevented most effectively by the elimination of the possible sources of infection, although in certain of the intestinal diseases immunization procedures are available which under appropriate circumstances may be of great value.

The administrative organization of a health department must be developed to meet the specific needs of the community which it serves. There are certain general principles, however, that may be defined. In order to control a disease it is necessary to know of its occurrence; therefore, morbidity and mortality reporting is required. In order to be effective, the health department must have some mechanism for obtaining reports of those communicable diseases about which some action can be taken to reduce the spread of infection or to prevent serious consequences. Reporting of communicable diseases should be required, the report being sent to the local health officer for his information and such action as is prescribed by the sanitary code or by administrative regulations of the department of health. Certain diseases, such as typhoid fever, smallpox and diphtheria, have become so rare in many communities that the services of an experienced and skilled diagnostician are of great value to the practicing physician and are usually greatly appreciated. In addition to the reporting of those communicable diseases for which some specific action may be taken by the health department, it is usually desirable to have requirements either in the public health law or in the sanitary code requiring the reporting by physicians or others of recognized unusual prevalence of disease or localized epidemics in order that attention may be called to the occurrence. The health department should have available trained personnel for the carrying out of epidemiological investigations wherever these are indicated and provide specially trained epidemiological teams of physicians, nurses and sanitarians to investigate and control the unusual prevalence of disease in any part of the state; special units may be necessary to deal with diseases of particular importance.

There are certain diseases for which there is available a reliable immunizing agent and the departments of health maintain active programs to promote immunization against these diseases. Important among these are smallpox, diphtheria, pertussis, tetanus and typhoid. Immunization against smallpox has been so amply demonstrated to be effective in controlling this disease that many communities have required that all children be vaccinated, either in infancy or at the time of entering

school. This is particularly true in urban communities. One of the responsibilities of the health department is to enforce such regulations or laws where they exist and to stimulate universal vaccination against smallpox regardless of whether legal requirements prevail in the state. Diphtheria immunization has also been proven to be of unquestioned value in the prevention of the disease and it has been demonstrated that epidemic diphtheria can be prevented by the immunization of a significant proportion of the population. Compulsory diphtheria immunization has not been generally accepted in the United States but there has been over the years a growing tendency to accept immunization in infancy as a standard practice. Most health departments maintain clinics for the immunization of infants in families unable to obtain this service from pediatricians or practicing physicians. Many communities maintain an accurate register showing the immunization of infants and requiring the reporting by all clinics and physicians of immunizations carried out in order to have assurance of an adequately immunized population for the purpose of preventing the spread of the disease. In the past decade, the protective value of pertussis vaccine has been demonstrated. Whooping cough has been added to the group of diseases for which active immunization is urged. Tetanus toxoid was demonstrated to be of unquestioned value, particularly during World War II, and, while tetanus is a relatively uncommon infection in civilian populations, the threat is always there and with the development of combined diphtheria, pertussis and tetanus vaccine there is a constantly increasing proportion of the population that is also immunized against this disease. (See Chapter 16.)

**Tuberculosis Control.** The measures taken by the health department to prevent tuberculosis are, in general, based upon removal of the open case of tuberculosis from contact with his family and the general population. This usually can be effectively accomplished only when such a patient can be hospitalized. The major effort of the health department is, therefore, to set up a mechanism whereby the disease may be recognized in its early stages so that the infectious case may be prevented from continued exposure of other individuals and so that the individual case may be given as prompt treatment as possible in order to minimize the possibilities of extensive disease or death. The case-finding program of the department of health is, therefore, one of the important features of the tuberculosis control program. Cases of tuberculosis may come to the notice of the health department in a number of different ways. They may be reported by private physicians, hospitals or clinics; they may be diagnosed from specimens submitted to the health department laboratory; or, unfortunately, they may come to the attention of the health department only through report on the death certificate. In recent years, extensive efforts have been made by health authorities to detect cases of tuberculosis early through mass screening, using the small film x-ray technic, of populations, particularly those known to be prone to tuberculosis. Facilities are rarely available for the immediate isolation or hospitalization of the recognized case; therefore, supervision of recognized cases within the home is one of the important activities of the health department.

Wisely used, a tuberculosis register provides an effective means whereby the health department may maintain supervision over all known cases of tuberculosis and may detect additional cases through the examination of family contacts. The adequate follow-up of known cases of tuberculosis requires frequent nursing visits;



this applies particularly to sputum-positive cases, all of which should be hospitalized at the earliest possible date.

In the United States, the use of BCG vaccination as a means of protection of particularly exposed groups is being explored. The establishment of an organization or a plan for the vaccination of tuberculin-negative infants in population groups known to have a high tuberculosis mortality is under consideration in many areas.

See Chapter I for a technical discussion of tuberculosis control.

**Venereal Disease Control.** The venereal diseases, of which syphilis and gonorrhea are the most common and most important, are highly prevalent in the United States. They differ from the other communicable diseases with which the health department has to deal in that they are contracted usually as a result of promiscuous sexual contact. Any reduction in the amount of sexual promiscuity would, without question, result in a rapid decline in the number of new cases of venereal diseases. Efforts through education to reduce the amount of sexual promiscuity have, however, been almost uniformly unsuccessful and such progress as has been made in the prevention of venereal diseases has resulted from other means. Principal among these has been the reduction of the period of infectivity of the individual case through prompt and effective treatment, thus diminishing the probability of infection of others. Probably the most effective procedure to attain this end is to make good treatment quickly and easily available to every infected person. This may be done by the establishment of public clinics or by aid to practicing physicians to whom patients may go. These means will be effective only if accompanied by the carrying out of an educational program which will bring to the attention of the infected person or the potentially infected person the seriousness of the diseases and the importance of adequate treatment. A large proportion of cases of syphilis and gonorrhea occur in persons who are unable or unwilling to pay for treatment. For these people health departments have had to organize free public clinics. If treatment clinics are to be effective, consideration must be given to the ease and convenience of the patients. For this reason evening clinics are almost invariably a necessity in any venereal disease control program. Modern methods of treatment, particularly with penicillin, have greatly reduced the problems previously encountered in keeping patients under treatment for a sufficient length of time to render them noninfectious and to provide reasonable assurance of cure. These new methods of treatment have, however, created additional problems, particularly in gonorrhea where the promptness of cure materially increases the possibility and probability of reinfection.

There are differences of opinion as to the values of contact investigation but the experience of competent investigators would seem to indicate that under some circumstances careful interviewing and detailed contact follow-up is an effective means of finding new cases and reducing the sources of infection. Organized prostitution is, without question, an important factor in the maintenance of gonorrhea and syphilis. The experience of World War II, when vigorous efforts were made to suppress prostitution, demonstrated that the suppression of prostitution has the effect of reducing promiscuity and, thus, the incidence of venereal diseases. The almost inevitable linking of prostitution with other forms of vice and the frequency of corrupt practices among law enforcement agents make the suppression of prosti-

tution extremely difficult at any time and only the continued exercise of strong pressure of public opinion will bring about consistent control.

See Chapter 4 for a technical discussion of venereal disease control.

**Maternal and Child Hygiene.** When in the last years of the nineteenth century the excessive mortality of infants and young children began to attract the attention of physicians and others interested in human welfare, very little exact scientific information was available as to the causes of the deplorable conditions which were everywhere evident in the large cities. It had long been known that the mortality of infants was many times higher among the poor than among the more fortunate classes of the population. It was known also that breast-fed babies had a much lower mortality than did those artificially fed, and that the intestinal diseases, diarrhea, enteritis and what was called "cholera infantum," were major causes of infant mortality during the summer months.

The first efforts to reduce infant mortality were based on the assumption that the high infant mortality of the summer months was due primarily to impure milk, with the ignorance of the slum mothers and the general effects of poverty and low living standards as contributory causes.

The milk station, designed to make pure milk available to the poor, early outlived its usefulness. The great improvement in the cleanliness and keeping quality of market milk and the spread of pasteurization soon made the general milk supply as well suited for the feeding of infants as were the certified supplies formerly produced for that purpose. Along with the improvement in the milk supply, other sanitary improvements were made in the cities. Water supplies were made safe from contamination, sewer systems were extended and privies abolished, particularly in the smaller communities. Finally, and by no means least in importance, the automobile supplanted the horse as a means of transportation and with the disappearance of the horse and stable, the fly population, even in midsummer, decreased to a small fraction of what it had previously been. The result of all of these improvements, and it is impossible to decide to just what degree any particular one influenced the result, was a rapid decline in the prevalence of "summer diarrhea" and of infant mortality resulting from it. A high infant mortality became a phenomenon of the winter months rather than the summer months.

The infant welfare station has survived as the well-child conference and has everywhere come to be recognized as the most useful agency in the child hygiene program. It is primarily an educational institution. In a well-organized city, the health department conducts a sufficient number of these stations to serve all infants not able to secure similar service from a private physician. Approximately 30 per cent of the infants and young children resident in a large city fall into this class. Such clinics must be widely scattered in the community so that mothers may conveniently take their children to them.

The staff of a child hygiene clinic consists of a pediatrician, a nurse and, if possible, a voluntary worker or clerk to assist the nurse and the mother. The children seen at any regular session should be those from the district of the nurse on duty at that time and she should, so far as possible, be present during the interview between the mother and the pediatrician.

The clinic should, as far as possible, avoid the treatment of sick babies. It is not staffed or equipped for such a purpose and an attempt to treat sick babies



is usually not only inefficient in itself but entirely destroys the educational feature of its activity.

Although the infant under two years of age was of first interest to workers in this field, it was not long before the services of the child hygiene clinics were extended to cover the whole of the first six years of life.

In addition to the system of clinics and public health nurses, various minor phases of the problem of infant and child health have received attention. Maternity hospitals and infant boarding homes were, in the early years, large contributors to the numbers of deaths of infants and young children, and their licensing and supervision by the health department was early undertaken. Within recent years the mortality of premature infants has been greatly reduced by the inauguration of special procedures designed to give these cases such care as will insure their survival and normal development.

The extension to rural areas of a system of infant hygiene service, based on infant welfare clinics, has been slow and difficult. In thickly settled suburban areas the work may be carried on as in cities, but in a rural county without a city and with a population dispersed over a large area a number of difficulties arise. There is available for service in the clinics no such supply of young pediatricians as is normally to be found in a city. The distances that must be traversed by mothers who wish to bring their babies to a clinic are so much greater that the question of transportation is of the utmost importance. In rural areas, also, the private physician is not accustomed to having his patients served by any outside agency and, since almost every infant is at least potentially the patient of some physician, the profession may object to the conduct of such a system of infant welfare clinics.

In spite of these obstacles, some states have made substantial progress in extending the work. In such cases, pediatricians employed by the state for whole or part-time service, conduct infant welfare stations at natural gathering places and at regular intervals. The rural public health nurses maintain contact with the mothers, securing their attendance at the clinics and helping them carry out in the home the instructions of the physician. Where such sessions can be held as often as once a month the interest and cooperation of the mothers can be maintained. Such programs are still in the developmental stage, however, and in no large rural areas are the child welfare services developed to the degree usual in the cities.

See Chapter 14 for a technical discussion of maternal and child hygiene.

**Maternal Hygiene.** The United States was one of the last of the great nations to undertake governmental procedures to reduce the morbidity and mortality incident to pregnancy and childbirth. The training of midwives has been almost totally neglected here and as a result millions of women to whom the services of a physician were not available have been delivered by ignorant "grannies" whose only training was the word-of-mouth instruction by others as ignorant as themselves. Even the training of physicians in obstetrics was, until comparatively recent times, incomplete and unsatisfactory. These conditions gave this country the unenviable distinction of an inordinately high rate of maternal mortality. Obstetricians, in caring for their private patients, early found that much was gained when their cases came to them early and were seen at regular intervals during the whole of pregnancy. Attempting to apply these principles to the whole problem of maternity hygiene led first to the

establishment of "prenatal clinics" on somewhat the same basis as the child hygiene clinic. These clinics, operated first as an experiment by voluntary organizations and later adopted by many health departments as a routine procedure, were very successful from some standpoints. The pregnant woman coming to them as soon as her condition could be recognized could be carefully examined and necessary treatment could be given and adequate preparation made for the delivery. Even the best service of such clinics, however, could not prevent the unfortunate consequences of a hurried, clumsy or dirty delivery. It then became evident that in the cities, at least, the mothers unable to employ a private physician must be given not only supervision during pregnancy, but also a satisfactory delivery. This can sometimes be furnished in the home but, in general, it has been found cheaper and better to care for these cases in a maternity hospital.

The system of maternity hygiene in a well-organized health department thus includes a service for registering women in the very earliest months of pregnancy; a system of prenatal clinics, held at easily accessible points with sessions at convenient hours, to provide supervision during the whole of pregnancy; and, finally, a delivery preferably in a hospital at public expense. Such a system must be able to serve one fourth or even one third of all the births in an average city.

In rural populations where the economic level is low and the service of a physician difficult to secure, the conduct of successful procedures for the improvement of the hygiene of maternity is considerably more difficult than in the cities. In some counties, as yet largely on an experimental basis, the health department contracts with the private physician for the delivery of indigent cases for a fixed fee and requires the physician to render efficient prenatal service. In other rural areas, however, the shortage of physicians makes this procedure impracticable, and the only thing possible is to endeavor to improve the service of the midwives who must still deliver a large proportion of the babies. Under such circumstances as these the health department must, if possible, operate prenatal clinics to serve all the cases of these midwives. It may also require them to provide the midwives themselves with at least a minimum of equipment and, through nursing supervision, to improve the quality of their work.

In certain rural areas, health departments are experimenting with a plan in which nursing service is provided the patient at the time of delivery by the private physician. A still further demonstration is that of the Frontier Nursing Service in the mountains of Kentucky. The population of the area reached by this Service is so isolated by the character of the terrain and its economic status is so low that the practice of medicine as generally carried on in rural areas is impossible. The Frontier Nursing Service operates a number of stations staffed by nurse midwives, most of whom have been trained in England, who themselves deliver the mountain women in their own homes. It operates a small hospital in the center of the area where complicated cases can be treated and where other serious illnesses can be cared for. This service, operating under conditions of extreme physical difficulty, has had a most satisfactory record of maternal mortality but operates at a cost per patient far beyond the resources of most rural health departments.

An interesting feature of the work of the Frontier Nursing Service is the establishment of a course of training for midwives. A similar course has been established in Alabama for the training of Negro midwives. The total number of graduates from



these courses is still too small to influence the situation notably as a whole but their establishment and survival represents a breaking down of the idea so long maintained by the medical profession of the United States that the midwife is not a necessary part of the medical picture.

See Chapter 15 for a technical discussion of maternal hygiene.

**School Health.** A necessary part of any system of compulsory education is adequate provision for protecting the health of the child while in the school. A necessary part of any school curriculum is teaching in the fundamental principles of healthful living. For these reasons the health service is a vital part of the public school system. Such health services are sometimes operated by the health departments and sometimes by the departments of education. There are advantages and disadvantages to both arrangements, and either can be made to operate satisfactorily with good will on both sides.

While the department of education has primary responsibility for the construction and maintenance of the school plant, the department of health should have opportunity to review all plans for new school buildings before contracts are let, and should make regular systematic sanitary inspections of every school building several times during each school year. The general cleanliness and state of repair of the school plant will be much improved if reports on these inspections are made to the department of education by the health officer.

Medical supervision of the child in school is of great importance. Its first purpose is to discover and, if possible, correct any condition which may interfere with the education of the child. Its further purpose is to contribute to the normal and healthy development of the child as a future citizen. An incidental purpose is to provide attention for the numerous minor ills and injuries which always develop when children gather in large numbers for any purpose.

Health supervision of the children began with an effort to have each school child examined by the school physicians at least once each year. The force available for such inspections was always inadequate and the amount of time allotted to each child was thus so short that only the most hurried inspection was possible. Large numbers of children were found, it is true, to have defects which should have been corrected. The defects so discovered were principally those of the teeth, of the nose and throat, and of the special senses. The mere discovery of these defects was, of course, without value unless facilities for their correction were at hand. This was seldom the case and the annual inspection frequently resulted only in the rediscovery of conditions previously noticed, and for which no corrective action had been taken. A large part of the time of the nurses was employed in this work and in the resulting effort to persuade parents to have the defects corrected. Where the work was conducted by the health department it was not unusual for two thirds of the working time of the nursing staff to be devoted to the school work with results of but little value.

More effective procedures have slowly been evolved and in many cities at the present time a real effort is made to shift as large a proportion as possible of the work of examining the children entering school each year to the family physician. The details of these examinations are reported to the health department on forms furnished by it. While in the beginning of such a system much of the work done by private physicians is superficial and of but little value, persistent effort will

induce them to regard the procedure as one of importance and to devote to it the time and effort necessary to a satisfactory examination. Once the child has been carefully examined by his family physician, the physician usually interests himself in securing the correction of any defects that in his opinion need attention, and the school nurse is thus relieved of much labor. As for those children entering school whose parents will not or, for economic reasons, cannot have them examined by the family physician, they must be examined by the school physician. The number of these is not so great but that they may be given a careful and effective examination. Having entered the school under this system, a child is then not re-examined until ready to enter high school unless his teacher observes some indication of a need for special examination, in which case such an examination is promptly made.

It is necessary also to establish a routine for the handling of children who become sick during school hours or who receive minor injuries. These matters are usually taken care of by the school nurse. The decline in the prevalence and in the seriousness of the communicable diseases of childhood has much diminished the load of service formerly required of the school physicians and nurses for their control, and the restrictions put upon other children from homes in which such diseases occur have been much relaxed. Still further relaxation in the future is probable. At the present time the communicable diseases which give the school and health authorities most concern are pediculosis and scabies.

The education of the child in the principles and habits of health is, of course, fundamentally the responsibility of the educational authorities. For a variety of reasons only rarely is it well done at present. The principles of healthy living are not easily reducible to simple statements which can be given the child to memorize. On the other hand, the scientific training of teachers in the elementary schools is not usually sufficiently broad to enable them to make the fundamental principles of the subject at once plain and attractive to children. Progress is being made in this regard, however, and it is to be hoped that the children of future generations will govern their lives more on scientific principles and less on hereditary fables and folklore.

See Chapter 17 for a technical discussion of school health.

**Services for the Physically Handicapped.** Many state health departments, recognizing the very serious problem of crippling conditions, established crippled children's divisions or orthopedic divisions, the purpose of which was to obtain information concerning the prevalence of crippling conditions and to provide some services for the rehabilitation of the physically handicapped. These services developed to the level of a major division of the state health department in only a few states prior to the stimulus that came from the enactment of the Social Security Act and the provision of federal grants through the Children's Bureau. Under this stimulus, there has been a very rapid development of state and local services for crippled children in which reporting has been greatly increased and registers of crippled children have been set up in many states. Under the provisions established as conditional for the receipt of federal aid, well-organized and efficient programs of rehabilitation of the physically handicapped have developed. Not all of the crippled children's services are located in health departments. Some are in welfare departments, some are in departments of education and some are independent com-



missions. Under these programs, provision is made for the necessary medical and hospital care for the correction of physical defects in children and for vocational training.

The organizational pattern most frequently found in state health departments is a division or a subdivision within the Bureau of Medical Services, not infrequently headed by an orthopedic surgeon, although there is a growing tendency to place general medical administrators at the head of these units. The staff of these divisions consists of orthopedic nurses, medical social workers and physical therapists. Orthopedic or plastic surgery is usually contracted for in existing medical facilities in the community. By far the majority of physically handicaps cared for under these programs are due to orthopedic disabilities. In recent years, the program of the crippled children's divisions has broadened in scope and has included such crippling conditions as rheumatic heart disease and cleft palate.

See Chapter 18 for a technical discussion of services for the physically handicapped.

**Public Health Nursing.** The division of public health nursing may be in the general grouping of medical services or it may be assigned to local health administration. Public health nursing is a service division which touches upon every activity of the health department. This division not infrequently represents more than half of the personnel of the health department. There is almost complete agreement at the present time that public health nursing services should be generalized insofar as possible and that an individual nurse not be assigned to any specific type of activity except in a consultative capacity, but that the staff nurse be assigned to a geographical area and carry out when possible all of the nursing functions for the population of that area. In determining the size of the area it has been generally found that a nurse can provide the services required by a population of approximately 5,000 people. It is, therefore, desirable to have at least one nurse per 5,000 of the population to be served. The nursing service is under the general supervision of the health officer but adequate supervision should be provided. One supervising nurse to 6 to 10 staff nurses is necessary if adequate supervision is to be provided. The activities of the public health nurse include home visiting to cases of communicable diseases, including tuberculosis and usually venereal diseases, at which time she plays a very important role in education of the family and in training members of the family to adequately care for the sick individual. In the maternal hygiene service the nurse plays an extremely important role, keeping in close touch with the expectant mother, particularly in the latter weeks of pregnancy, and not infrequently carrying out under supervision such technical procedures as taking blood pressures and doing urinalyses. In the child hygiene program she not only assists at the well-child conferences but through home visiting maintains a continuous contact with the family, assists the mother in the care and feeding of infants, and maintains the continuity of contact between the health department and the child. It is largely through her efforts that a high level of immunity to smallpox and diphtheria is maintained in the community. In the generalized service, the nurse also has important responsibility in the school health program, assisting in examinations and, through her periodic conferences with teachers, screens out those children requiring further medical attention.

The public health nurse is also in a particularly advantageous position to assist

in the mental hygiene program. She is the member of the health department team most apt to be in a position to detect emotional disturbances or mental illness at an early stage and, if she is alert to this possibility, she may serve as a most effective screen for those individuals requiring further attention or clinic treatment. As health departments undertake more and more activity in the field of chronic diseases, there is particular need for bedside nursing care. In many communities voluntary nursing associations have traditionally provided this service and many have assisted in the routine public health nursing services. There is growing interest in a combination of the official public health nursing services and the voluntary bedside nursing programs. In a number of cities, apparently happy integrations have been effected in which these two services have been merged, making possible a more efficient utilization of the nurses in both organizations. If a complete bedside nursing program is to be undertaken, it is estimated that one nurse to 2,000 or to 2,500 of the population will be required. With the increasing importance of chronic diseases as a public health problem, there seems to be a growing need for this type of service which can probably be best provided in those communities where visiting nurse services are already established through such a merger.

**Mental Hygiene.** Mental hygiene is one of the more recent additions to the program of health departments. Until recently, mental illness was considered primarily a problem for hospital care and, unfortunately, usually only custodial care. With the growing recognition of the possibilities of prevention of emotional or mental disturbances, and with the increased recognition of minor disturbances and behavior problems, there has been a proportionately increasing demand that provision be made for the care of these cases. State hospital systems have been loathe to undertake this program and, because of the possibility of prevention in many types of emotional or mental disturbances, health departments have been urged to undertake this program. There are some very good reasons that can be put forward for the placing of this responsibility upon the health department. In the first place, members of the staff of the health department have broad contacts with the population, coming in contact through various clinical activities and through the nurses' home contacts with a significant proportion of the population. Furthermore, many of the behavior problems which require attention occur in preschool and school children, the physical well-being of many of whom is already the responsibility of the health department. Moreover, the health department represents the only medically oriented group in most governmental units. While it is true that most health officers are not qualified in psychiatry and few public health nurses have had training in mental hygiene, they have had basic training which would make the development of these additional skills feasible. Also, it has been traditional in health departments to seek specially qualified personnel for special activities. The establishment of mental hygiene clinics, under the direction of competent psychiatrists, psychologists and other necessary technical personnel, within the general administrative structure of the health department is not an unfamiliar pattern. It is also apparent that the mere establishment of a clinic is not all that is necessary. The social structure of the community must provide for the screening of those individuals who require this service from the general population. This can be done in the well-child clinics by properly oriented staff, by public health nurses who have had some training in mental hygiene, by school teachers, school psy-



chologists, and practicing physicians who are accustomed to working closely with the health department. The extent to which mental hygiene services may be needed in a community is not well known as yet. There is great need for further study of the extent of the problem and of the effectiveness of proposed methods of dealing with these problems. This cannot be done in a vacuum; carefully organized and operated programs in health departments may well help to answer these perplexing questions.

See Chapter 20 for a technical discussion of mental health.

**Adult Hygiene.** The reduction in morbidity and mortality which has been so encouraging in the past 50 years in the United States has been largely due to the reduction in infectious diseases and in the reduction in infant mortality. This has resulted in a change in the most important causes of death, a general aging of the population, and an actual increase in crude death rates from such diseases as diabetes, cancer and heart disease. There are differences of opinion as to whether these increases are actual or whether they are the result of better diagnosis. In either case, the fact still remains that these diseases are the most important causes of death and that if continued progress is to be made in the reduction of mortality these are the fields which must be given attention. Unfortunately, we have no simple preventive measure for any of these chronic diseases of middle and old age. In the light of present knowledge, the only approach possible is through early detection and adequate treatment. The idea of periodic physical examinations advocated so strenuously has not proved particularly effective, nor is it feasible for most of the population. Either the examination is so extensive and time consuming and requires so many laboratory tests as to be extremely expensive, or it is so inadequate as to be almost valueless. Education has been put forward as the only effective means of approaching the problem and there can be no doubt that well-planned and intensive educational campaigns which emphasize the importance of early diagnosis and point out both the danger signals and the necessity for medical attention when these are present, have a place in any program directed toward these diseases. Recently, hope has been raised that simple inexpensive screening methods for the early detection of at least some of these chronic disease problems will be developed; a promising example is the use of the small chest x-ray for the detection of lung cancer and certain types of heart disease. Simple laboratory tests for the detection of diabetes and, perhaps, other metabolic diseases seem to be within the realm of possibility. New and simple laboratory technics for the detection of uterine cancer and possibly small-film gastric x-rays for the detection of gastric cancer at an early stage also offer promise. None of these screening tests has as yet been adequately evaluated but carefully controlled studies by health departments seem to be indicated.

Industrial hygiene activities have developed along several different lines. In some states industrial hygiene has been a function of the labor department, where it was developed largely as a program directed toward the elimination of occupational hazards and the provision of general hygienic working conditions in industry. In recent years there has been a general tendency to broaden the scope of industrial hygiene to provide general health supervision for employed persons. In this broad sense it is a logical activity of the health department and one for which the health

department is probably the government agency best prepared to render this service. The program of industrial hygiene within a health department should include, in addition to the measures necessary for the prevention of specific occupational hazards, the promotion of a general health program for industrial workers. This general health program should cover general sanitation of industrial plants with proper attention to lighting, ventilation and other general conditions of housing; and, more important, it should promote pre-employment examination with work assignment in accordance with physical findings, a general medical and nursing service which would provide for correction of physical defects, and a program of public health education. Such a program would benefit not only the worker himself but also his family. In setting up such a program the staff should include a physician, an engineer, a chemist, and nursing service adequate for the population to be served.

See Chapter 19 for a technical discussion of adult hygiene.

**Hospital and Medical Care.** In recent years, health departments have assumed greater responsibilities in the field of hospital service and medical care. Particularly as a result of the Hill-Burton Act in 1946, state health departments were given the responsibility for surveying and planning for hospital facilities throughout the state. Also as a prerequisite for receiving federal funds for hospital construction the states were required to set up hospital licensure programs. This involved the review of existing hospital facilities, the establishment of standards for licensure and a continuing program of hospital inspection. State health departments were also given the responsibility of administering under advisory boards the funds made available to the state for hospital construction. As chronic disease programs have developed in state health departments, an important part of these programs in many states has been the development of chronic disease hospitals, again adding to the responsibilities in hospital administration already carried by the health department. In some states and cities the health department has been charged with administering programs of medical care for the indigent. Such programs usually involve the health department only in the administration of the program through contracts with existing medical facilities, such as hospitals and clinics, and with practicing physicians.

**Other Activities of State Health Departments.** The recognition of the importance of accidents, particularly home accidents, as a cause of death has stimulated the development of active programs of accident prevention in a number of state health departments. These activities may take the form of general education, as a part of the health education program, calling attention to the importance of accidents as a cause of death and disability and pointing out the factors involved in accident production. In other programs, inservice training for all health department personnel has been carried out with the idea that education in accident prevention shall become a routine part of the program of both public health nurse and sanitary inspector.

The importance of nutrition in the promotion of health has also been recognized as a field for possible health department influence. Here again, education is one of the best known approaches to the problem, although in some health departments provision has been made for clinical examination for the detection of malnutrition.

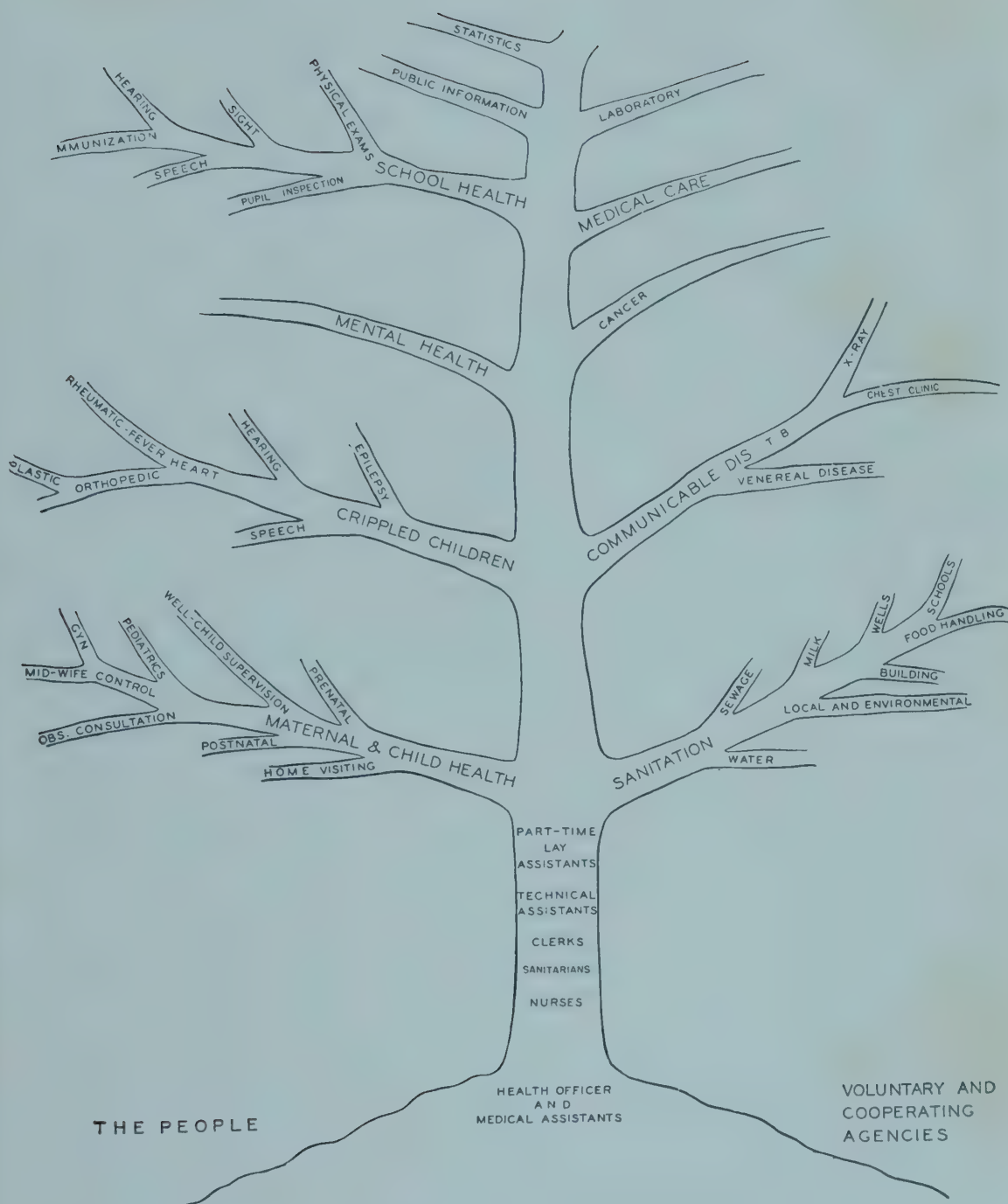


## THE BUREAU OF LOCAL HEALTH ADMINISTRATION

The function of a bureau of local health administration depends somewhat upon the organization of the state. In a few states the area of the state has been broken up into districts headed by a district health officer who is a full-time employee of the state health department and serves as a representative of the state health officer in dealing with local health departments. His function is to stimulate more adequate local health services and to serve as an advisor or consultant to local health officers or other local personnel. This method resulted in improvement wherever it was used but there is general agreement that the development of municipal and county health departments, with a reasonable degree of autonomy, is a more effective method of providing local health services. The bureau of local health administration is the unit of the state government which maintains general supervision over the activities of these more or less autonomous local health services, establishing minimal standards of operation in accordance with state law and providing advisory and consultation services to the local health units. In most states the bureau of local health administration is responsible for the administration of the program of state aid to local communities for health services. In a number of states the responsibility for recruitment and training of public health personnel for the state and local communities rests with the bureau of local health administration.

**Public Health Education.** No health program can be effective unless it can be brought to the people who need it and is acceptable to them. This depends upon an understanding of the basic principles of preventive medicine by the people who are to be served. The health department, therefore, must bend every effort to educate the population in the need for preventive services in order that they will seek them. Education of the public is not easy. It should begin in childhood; thus, an effective program of health education should be a part of every school system. In addition, adult education is necessary and is usually the field in which the health department plays the most important role. The health educator should be skilled in educational techniques and should be adept at community organization in order to make possible the most effective and most economical dissemination of health information. He may use all of the various media of communication, including the newspapers, the radio, motion pictures, and television, to the fullest extent. However, every member of the staff of the health department is in a position to assist in a program of health education. The public health nurse in her daily duties is doing one of the most effective educational jobs conceivable. The sanitarian in his regular visits has an opportunity to reach many people in a most effective way. The health officer himself has very definite responsibilities for general public education.

**Dental Health.** The frequency with which dental caries is found in young adults and adolescents clearly indicates the need for a preventive program which would, if possible, prevent these occurrences and the eventual loss of teeth. For many years the major emphasis was placed upon the cleaning of teeth and the slogan "a clean tooth never decays" was widely used. It is now generally agreed that this is not a sound basis for the development of a dental hygiene program. During the past 15 years there has been a tendency to discard this point of view and to attempt to provide actual preventive dental care, recognizing that early correction of defects in enamel will arrest caries. Education in nutrition has also been



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Fig. 48-2. State department of health and county government.



emphasized as part of a dental hygiene program. The fairly recent evidence of the value of topical application of sodium fluoride in the prevention of dental caries has completely revolutionized the dental hygiene program of health departments. The fluoridation of water supplies deficient in this element also offers very real promise of a mass approach to improvement in dental health.

**Public Health Laboratory Service.** Public health laboratory services are among the oldest functions of a health department. Most state health departments maintain laboratories which provide various types of service, including bacteriological diagnosis, serological testing and chemical testing. Some health departments also maintain biological laboratories for the production of standard biologicals for the prevention and treatment of diseases of public health significance. The diagnostic laboratories of a state health department should be staffed by competent bacteriologists and serologists prepared to carry out all of the standard laboratory tests of value in the diagnosis of communicable diseases. The chemical laboratories carry out standard chemical tests on water supplies, and milk and food examinations. Depending upon the size of the state, the central state laboratory may serve the entire state with the provision of an adequate mailing system. More frequently, however, branch laboratories under the supervision of the director of the state laboratories are established in strategic positions throughout the state, providing service for specified areas in which they are located. In a few states, instead of, or in addition to, the state laboratory and the branch laboratories, there is a system of approval of local laboratories for certain procedures of public health importance. This approval may be based upon an elaborate system of testing the quality of the work done in the laboratories or it may be based primarily upon the qualifications required for the directors of these laboratories.

## LOCAL HEALTH SERVICES

## MUNICIPAL HEALTH ADMINISTRATION

Municipalities are secondary governmental units resulting from the incorporation of certain areas within the primary governmental unit, the state. The state is the sovereign power, but municipalities are granted certain powers and privileges, usually by special charter from the state. Municipalities are given varying degrees of autonomy by the state government, from almost complete autonomy, as in the case of New York City, Baltimore, San Francisco and a few other major cities, to a directly subordinate position of the smaller cities within a state. The health organization in a given city is determined very largely by two factors: (1) the degree of autonomy granted to the city by the state government, and (2) the per capita wealth or the per capita tax income of the municipality. It is impossible to describe a typical municipal health department because the health organization of any municipality depends upon so many different factors. There are however certain basic functions of a municipal health department.

The modern city must render effectively a wide variety of services if the health of its people is to be preserved. In the United States, city governments present many interesting differences but these differences are manifested mainly in the forms of organization of their legislative and executive branches or of administrative organization. However, in the operation of their service departments they are strikingly alike. The average city government has certain specific functions to perform. These include the maintenance of public works and the development of public services such as education, welfare, safety and health. There are usually a number of departments of government created to carry on the necessary activities of a city government, depending somewhat upon the size of the community. In the larger cities these functions may be minutely subdivided, whereas in the smaller cities they may be combined into not more than two or three major branches of the city government. Many of the branches of the city government have some bearing upon the health of the community. The department of public works is usually responsible for the construction and maintenance of the physical facilities maintained by the city government, such as streets, sewers, parks, public buildings, etc. The development of an adequate, basic source of water for a municipality is not infrequently the responsibility of a department of public works or a similar municipal authority. The basic planning for such a water supply and the development of the necessary physical facilities for the maintenance of an adequate water supply are not infrequently entrusted to a branch of the city government not primarily concerned with the public health aspects of this supply.



The department of education is usually a separate agency whose primary purpose is the maintenance of a sound educational structure in which the maintenance of the health of the school child may or may not be of major concern. In many cities the department of education maintains a separate and autonomous health service whose purpose is to maintain the facilities to promote the health of school children. In other municipalities the health services for the school child are a responsibility of the department of health working closely in cooperation with the department of education.

In many cities the development and operation of public hospitals and the maintenance of health and medical services for the indigent are a responsibility of a department of welfare. There is a growing tendency to separate the strictly medical aspects of the welfare program and assign these responsibilities to the official health agency.

The police department is charged with the responsibility of maintaining an adequate program of law enforcement which includes the enforcement of public health law and sanitary code regulations. As the program of accident prevention has progressed, the police department plays an extremely important role in the prevention of accidents, particularly traffic accidents. The fire department is a major department in most municipal governments and has certain responsibilities in the maintenance of health and the prevention of death and disability from fire and fire hazards. Within recent years there has been a general tendency to create within municipal health departments an active program of accident prevention in which the police department is primarily responsible for the development of a program for prevention of traffic accidents, the fire department for the program of prevention of certain types of accidents, and the health department for the prevention of home accidents, as a rule in close cooperation with these other departments.

The health department is usually responsible for those activities which are primarily designed to protect or promote the public health. It is the responsibility of the health department to coordinate and integrate the health activities of other municipal agencies in order to provide a well-rounded and well-integrated program. The health department is usually a major subdivision of the city government and is responsible directly to the mayor or city manager or other executive officer. Historically, the earliest form of municipal health agency was the "board of health." At first this municipal health organization consisted only of a group of physicians or other public-spirited citizens called together in time of epidemic to advise the city fathers how to prevent the introduction or spread of communicable diseases. Gradually this temporary, relatively unorganized function developed into a permanent municipal organization maintaining regular services and functions which include environmental sanitation, the prevention and control of communicable diseases, the prevention and elimination of nuisances and the supervision of establishments for the production, distribution, and serving of food. Early in the development of municipal health organizations one of the most important activities was the supervision of the methods of disposal of garbage and other refuse. In the early history of the municipal health departments these environmental safeguards were considered to be of primary importance and the staff of municipal health

departments consisted mainly of vaccinators, quarantine officers and sanitary inspectors.

As the relative importance of environmental sanitation and quarantine procedures was recognized to be secondary, toward the end of the nineteenth century municipal health departments embarked upon a program of personal and community health. They placed increasing emphasis upon the clinical aspects of disease prevention and upon the detection and treatment of tuberculosis, the venereal diseases and the acute communicable diseases. At the same time, with awareness of the extent of maternal and infant mortality, they developed more and more elaborate programs of maternal and child hygiene. The first quarter of the twentieth century was a period of rapid development of preventive medical services on a community basis, particularly for the younger age groups of the community. It was during this period that the programs of maternal and child health were most rapidly expanded. In many municipal health departments from 50 to 75 per cent of the resources of the department were devoted to prenatal and postnatal health services, the development of a program of well-baby clinics and the development of school health services.

There can be little doubt that this phase of health department activities contributed greatly to the reduction in morbidity and mortality from the diseases associated with childbearing and the diseases of infancy in early life. The marked reduction in morbidity and mortality in childhood, youth and middle age has increased the relative importance of the diseases and disabilities of old age and, at the same time, has caused a significant change in the age distribution of the population. This has quite naturally resulted in a markedly changed emphasis in municipal health activities.

The position of the city health officer is today a highly important one. It demands possession not only of detailed and accurate scientific knowledge but also a high degree of administrative skill. The health officer is almost always a graduate in medicine and is more and more commonly required to have special training in public health and preventive medicine before he is permitted to assume his duties as a city health officer. He is given wide authority and at his discretion may perform acts which are possible to no other agent of the government. The personnel of a city health department includes individuals with many types of skills and training. In addition to the health officer, there are many other medical men with experience and training in administration and in the various specialties of medicine. In the larger organizations many of these will be specialists in public health and preventive medicine and will limit their practice to this field. Others serve the department of health in a part-time capacity, devoting the remainder of their time to private practice. The professional personnel participating in a municipal health program may include dentists, veterinarians, sanitary engineers, statisticians, chemists, bacteriologists and educators. The largest professional group in the health department is the public health nursing group. In most municipal health departments the public health nurses constitute approximately one half of the total staff. Another important component of a health department staff is made up of sanitary inspectors under the supervision of trained sanitary engineers. In the larger cities, public health laboratories are maintained which include bacteriologists, chemists and a wide range of specialists in diagnostic procedures. In some of the very large cities, there are



divisions of research which have carried on more or less elaborate programs of research in the communicable diseases and other phases of public health activity. In a few cities, biological laboratories are maintained for the production of certain types of biological products important in the maintenance of the public health.

The size of the staff of a city health department depends primarily upon the size of the population to be served. There are certain basic standards which have been established for the various types of health department personnel. It is generally recognized that at least one medically trained staff member is required for each 50,000 of the population, at least one public health nurse for each 5,000 and one sanitarian for each 10,000 to 15,000 under the adequate supervision of a sanitary engineering division, with sufficient specialized medical personnel to meet the clinical needs of the community based on the prevalence of such diseases as tuberculosis and venereal diseases, and on the general economic status of the community.

If the personnel employed by a municipal health department is to effectively carry out the functions assigned to it, there must be adequate provision for organization and supervision of the many and varied professional skills. This organization must bring together a group of health workers having widely varied training and experience and integrate this program into a co-ordinate whole. The executive officer of a municipal health department is responsible for the development of a well-organized and a well-rounded program of services in many specialized fields of health activity. Professional and technical personnel must be employed and trained, and facilities must be supplied for the efficient operation of many types of activities. In the plan of organization provision must be made for all types of services, and competent business management must be provided to assure efficient operation. In a municipal health department these activities are usually under the immediate direction of the health officer. Also under the immediate direction of the municipal health officer are certain generalized services necessary for the efficient planning and operation of a municipal health department. These include such activities as the collection and dissemination of vital statistics, the maintenance of adequate laboratory facilities for the diagnosis of infectious diseases, the distribution of necessary biological products, the maintenance of the necessary relationships with other municipal departments, and satisfactory public relations.

The city health department provides direct services to the population under basic guiding principles established by the state. The service organization of the municipal health department depends to a great degree upon the size of the city. The organizational pattern is based upon the various types of skills required in rendering direct service. Environmental control in all except the smallest cities is under the direction of a sanitary engineer, with a staff of subprofessional personnel carrying out the various inspection services to maintain adequate sanitary precautions. The clinical services in the smaller cities are under the direction of the health officer himself and in the larger cities, there are varying degrees of specialization. Depending upon the size of the city, there may be a division of communicable disease control which may include tuberculosis and venereal disease control, or these two latter programs may be in separate divisions. Again, in the larger cities maternal and child health may be set up as a divisional activity whereas in the smaller cities these may come under the direct supervision of the medical officer of health. Nursing services are almost without exception under the direction of a

supervisor of nurses and, at the present time, with very few exceptions, this is a generalized service covering all branches of the health department's activity.

Statistical services in a municipal health department may be extensive or very limited, depending upon the size of the community and upon the public health laws of the state. Usually, in the very large cities, there is a division of vital statistics which maintains a system of recording births, deaths, marriages and divorces, reporting to the state health department. In smaller cities, there is usually a local registrar who receives at least birth and death certificates and transmits these to the state health department, maintaining little or no provision for analysis. Municipal health departments vary considerably in the provision of laboratory services. In the larger cities, complete diagnostic service may be offered by the city laboratory, and there may be provision for the distribution, if not the production, of biological products. Medium-sized cities not infrequently maintain a branch laboratory of the state health department, and in the smaller cities reliance is placed upon the state laboratory for all except the simplest laboratory procedures. In recent years, there has been a growing tendency for city health departments as well as other levels of public health administration to develop programs in the field of chronic diseases. These services may include cancer detection clinics, cardiac classification services, diabetic clinics and, with increasing frequency, the so-called multiphasic screening programs. In a few cities, chronic disease hospitals have been established for the provision of institutional care for the chronically ill. In a limited number of municipalities the provision of medical care for the indigent has been made a responsibility of the municipal health department.

The size and complexity of the organization of these activities in any health department depend upon its resources and vary, in general, directly with the size of the city. In the smaller cities the organization is comparatively simple, while in a great metropolis it becomes exceedingly complex. In the large cities, the problems of organization are complicated not only by the number and the diversity of personnel and of function but by the factor of geography. The distances to be traversed by physicians, nurses and inspectors reporting for duty and then proceeding to their fields of work, the mass of records to be kept in the central office, and the isolation from the actual field activities of the principal executives of the department, all become serious obstacles to effective and economical operation. To meet these conditions, some of the larger cities in the United States have set up a system of decentralization. A large city is thus divided into districts of appropriate areas with populations varying from 100,000 to 300,000 persons. Each district becomes in a sense the health department serving the population of the district with its own health officer and its own staff. This district staff works under the general control of the central office which is responsible for the development of general policy, while the district staff is responsible for the provision of direct services. There are certain services which do not lend themselves readily to decentralization. For example, milk sanitation in a large municipality requires a field inspection program in rural areas and a highly technical service for the inspection and approval of pasteurization plants which not infrequently serve the entire city. Supervision of water supplies and sewage disposal systems do not readily adapt themselves to decentralization. Even in the acute communicable diseases, there are certain difficulties in delegating authority to a local district, in that an epidemic may be city wide or may



not recognize district lines. Service programs which include maternal and child health, public health nursing, restaurant sanitation, health education and chronic disease programs do, however, lend themselves readily to a program of decentralization with administrative authority in the district health office. The age-old problem of line and staff relationships not infrequently makes decentralization a serious problem in many cities but the advantages of the development of a feeling of community pride in its health program and the possibility of community organization on a district level make this type of organization desirable in all except the smaller cities.

With the increase in clinical activities in the health department, there is a need to bring these clinical facilities to the people. This has been done through the development of a network of clinics throughout the city. With decentralization, there were many advantages in the creation of a health center. This health center may become a community center which houses the district administration and the clinical services and serves for general community organization. Health centers should be located at strategic points throughout the city, with consideration given to the location of the population having the greatest need for the service of the health department, and with due attention to lines of transportation. The number of health districts per unit of population depends upon the density of the population. In some cities, there may be need for one health center per 50,000 to 75,000 of population, whereas in a city such as New York City a health center may serve a population of from 200,000 to 300,000 people.

Health centers must be designed to meet the specific needs of the area to be served. Adequate space and functionally planned clinics to provide all of the direct personal services of the health department are extremely important. Another important consideration is the housing of closely related services. It has been found of great advantage to provide space in the district health center for certain non-official agencies, such as the visiting nurses service and certain of the voluntary health agencies dealing with specific diseases, such as the tuberculosis association and cancer and heart societies, etc. The close proximity of these agencies to the official health agency tends to produce much closer and much more effective working relationships.

There is a growing tendency for municipal health work to be supported jointly by municipal appropriations, state aid and, indirectly, federal aid to local health services. This is a natural tendency with the concentration of the taxing power in the state and federal governments. Not many years ago a per capita expenditure of \$1.00 was considered reasonably adequate, but with the general inflationary tendencies in the United States and with the rather general expansion of the scope of health services, per capita costs have gone up. Two and a half dollars per capita has been reached by a number of cities exclusive of any hospital costs and these costs are still rising and approaching \$3.00 per capita in some cities.

### RURAL HEALTH ADMINISTRATION

Rural health services have developed slowly in the United States in spite of the fact that local boards of health have been in existence in certain states for more than 150 years. One of the obstacles has been the lack of uniformity in local

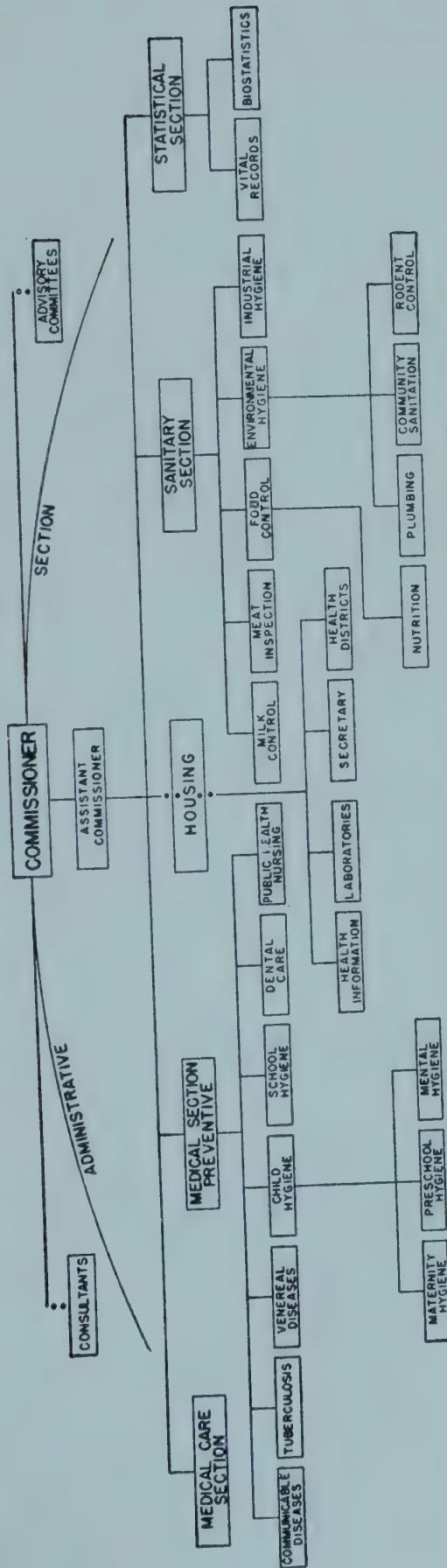


Fig. 49-1. Organizational chart—Baltimore City Health Department.



political subdivisions within states. In the New England States, the town, township or village has been the important unit of local government whereas in the southern and western states, the county is the unit. It is generally recognized that full-time health services require, in most instances, a population unit approximating 50,000 persons. Most of the towns and villages and many of the counties are much smaller than this. There has been an increasing pressure for combinations of local units in order to provide adequate health facilities. This movement, however, because of local pride and other factors, has progressed very slowly. Another factor that may have been important has been the rather prevalent belief, at least until fairly recently, that rural areas were inherently healthful and that the health services recognized as necessary in urban areas were not needed in rural areas. This fallacy has been largely dispelled through the publicizing of actual morbidity and mortality statistics for these areas. Furthermore, the importance of the problem of rural health in any national program is emphasized by the proportion of the population living in rural areas. Approximately 65 per cent of the population of the United States, according to the census of 1940, resided in unincorporated or in incorporated areas of less than 50,000 population.

The first permanent county health organization was established in Yakima County, Washington, in 1911 and, like most specific movements for the improvement of the health, it was the result of a disastrous epidemic. At the present time, between one third and one half of the counties in the United States have established full-time county units and it is estimated that approximately one third of the population of the United States still does not have the benefit of even the minimal standard of rural health service. Various methods have been tried to bring local health services to rural communities, the most important and the most effective of which has been the county health department. A few states have attempted to provide rural health services through state districts in which the state health department gave a certain amount of direct service to rural communities which has been supplemented usually by county, town or village health services, particularly in the public health nursing field. It is now quite generally agreed that the minimal population which can support an adequate health service is 50,000 and efforts have been made to group counties of lesser population together as a unit. Another movement is the tendency to develop a joint health department program for cities and the surrounding rural areas.

In the organization of county health departments or multi-county district units, there are certain basic standards that are now generally accepted. Minimum requirements for efficient operation are one medical officer of health per 50,000 of population, one trained public health nurse for every 5,000 of the population if bedside nursing is not included in the program and one to every 2,000 to 3,000 of the population if bedside care is provided, one sanitarian to 10,000 to 15,000 of the population (provided there is adequate supervision from the sanitary engineering division of the state health department), and sufficient supplementary clinical personnel to meet the basic needs of the community. The program of a county health department or a county health district includes the basic services for the protection of the public health. Provision must be made for environmental sanitation with special emphasis on the safeguarding of individual water supplies and sewage disposal systems, the protection of individual and small public milk supplies, and the prevention of

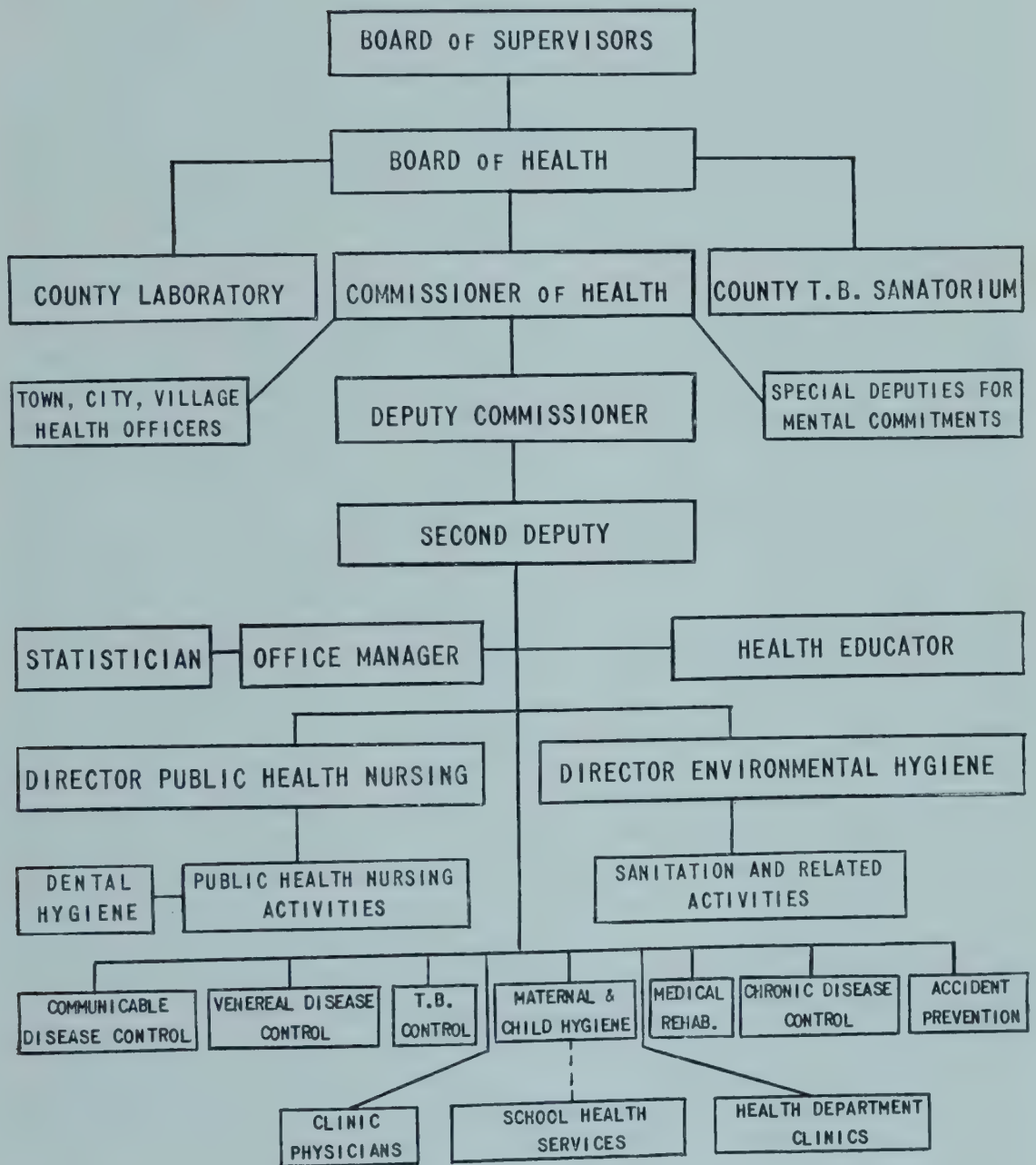


Fig. 49-2. Organizational chart—Rensselaer County Health Department, Rensselaer County, New York.



nuisances. In some communities this can be primarily an educational and consultative function; in others, such as in the southern United States, an active program to develop safe and protected individual water supplies and the building of sanitary privies is an important activity. In communicable disease control, the basic principles are the same as in their application in urban communities, complicated only by the distances to be traveled. The requirements of the county in the program of tuberculosis control, venereal diseases control, and adult hygiene, as well as maternal and child hygiene, include the provision of clinical services adequate for the population. This may involve either the establishment of small rural health centers or, under certain circumstances, traveling clinics.

The health department designed to serve a county should be an integral part of the county government and the county should contribute to its support. County government in the United States has traditionally been carried on by boards of commissioners or supervisors and there is seldom any real executive authority under which the health department may operate. It is usually advisable, therefore, to create a county board of health under whose supervision the health department may be placed. Such a board should not be given any executive or administrative powers that might hamper the health officer in the conduct of his work. As in all other fields of health activity, every effort should be made to remove the health department insofar as possible from partisan political influence. Since county government is usually supported by taxes levied on real property and since real property no longer constitutes the principal form of national wealth, it is exceedingly difficult for the counties to finance the expanding programs of social service of which health is such an important part. It becomes necessary, therefore, for the states to use their taxing powers to supplement those of the counties and to contribute to the support of these services. The federal government may also use its taxing powers and contribute funds to the states for these purposes.

Various inducements have been offered to stimulate the development of county health departments. Almost all states now make some provision for financial aid to county health programs. The amount of state aid varies very widely and is not infrequently on a graduated scale, giving the greatest support to the counties least able to maintain an adequate county health service from local funds. The per capita cost of maintaining an adequate county health program varies considerably in different parts of the United States. With the 1950 value of the dollar an expenditure of less than \$1.00 per capita would almost certainly be inadequate and an expenditure of from \$2.00 to \$2.50 per capita is not unusual.

## INTERNATIONAL HEALTH ORGANIZATION

Since ancient times, the spread of epidemic disease from country to country has shown the need for international cooperation for health protection. The great epidemics of the Middle Ages were thought to have been introduced into Europe from the East, and local or national quarantine was established in an effort to prevent the spread of plague or cholera. Venice, in 1328, established what seems to be the first formal quarantine organization for this purpose and was followed by many city states but there seemed to be no coordinated effort in this direction until 1831 when, with the threat of the reintroduction of plague through the Middle East, the Egyptian Quarantine Board was formed. This Board was made up of the consular authorities of European nations in Alexandria and served as an advisory body to the local government but had no authority and was shortlived. The repeated appearance of cholera in Moslem pilgrims to Mecca was recognized as a serious threat to Europe, and upon the insistence of a number of European nations a "Superior Health Council" was created in Turkey in 1838 consisting of four Turkish representatives and one representative of each of the major European powers. This Council established quarantine regulations and supervised shipping from Turkish ports to ports in Europe. The Council went through periods of varying activity until it was finally abolished in 1923. Similar efforts were made in various parts of eastern Europe but were for the most part temporary and stimulated only by immediate threat of introduction of epidemic disease.

The first formal International Health Conference was held in Paris in 1851. This Conference was attended by representatives of 12 nations and the first treaty dealing with sanitary conventions was drawn up and signed by the representatives attending. However, this treaty, designed to limit the spread of epidemic disease with certain limitations upon commerce, was ratified by only three nations, two of which renounced it later. This first Conference was followed by a series of similar conferences, the primary purposes of which were the drafting of international quarantine regulations.

## L'OFFICE INTERNATIONALE D'HYGIÈNE PUBLIQUE

There was, however, growing recognition of a need for a more formal and more permanent international health organization and at the Conference in Rome in 1907, approval was given for the establishment of a permanent International Health Organization with offices in Paris and with a professional secretariat. The purposes defined for such an organization were to receive notification of such diseases as plague, cholera, smallpox, typhus, and yellow fever from the partici-



pating nations and to transmit this information to the member nations through diplomatic channels. A further purpose was the study and development of sanitary conventions and quarantine regulations on shipping and train travel. In 1909, L'Office Internationale d'Hygiène Publique was established in Paris to carry out the above functions. L'Office was maintained through financial contributions made by the member states. It continued to function after a fashion until it was absorbed by the World Health Organization in 1947.

In the Americas, international health organization may be said to have been initiated by a Regional Health Conference held in Rio de Janeiro in 1887 at which Argentina, Brazil, and Uruguay approved a regional sanitary convention dealing with quarantine regulations, particularly relating to yellow fever.

### PAN AMERICAN SANITARY BUREAU

The first International Conference of American States, held in Washington in 1889 to 1890, approved of the provisions of the Rio de Janeiro convention for general application to the American states. The second Conference of American States, held in Mexico City in 1901 and 1902, authorized the establishment of an International Health Organization. This Conference adopted the following resolutions:

1. That the governments represented at this Conference shall cooperate with each other . . . towards securing and maintaining efficient and modern sanitary conditions in all their respective ports and territories to the end that quarantine restrictions may be reduced to a minimum and finally abolished.

2. That a general convention of representatives of the health organizations of the different American Republics shall be called . . . that said convention shall provide for the holding of subsequent sanitary conventions at such regular times and at such places as may be deemed best by the convention, and that it shall designate a permanent executive board to be known as the International Sanitary Bureau with permanent headquarters at Washington, D. C.

3. That the office expenses of special investigations together with those for the translation, publications, and distribution of reports shall be paid from a special fund to be created by annual appropriation by the republics represented in such convention.

As a result of this action, the first general International Sanitary Conference of the American Republics met at Washington in 1902 and organized the International Sanitary Bureau. Since that time, the Pan American Sanitary Conference has met periodically and has considered all matters pertaining to the public health within the member nations. The International Sanitary Bureau became the Pan American Sanitary Bureau in 1924 when it became a regional office of the Health Section of the League of Nations. The specified functions of the Pan American Sanitary Bureau include the following:

1. To collect and disseminate epidemiological information.
2. To act as a consulting bureau to all of the member states.
3. To improve health administration in all of the member states.
4. To promote liaison between health organizations of the member states.
5. To prevent epidemics.
6. To establish quarantine measures of a minimal nature consistent with the prevention of spread of disease.

In 1924, the Pan American Sanitary Code was drafted, establishing the Bureau as a more or less independent agency operating under the direction of the Pan

American Sanitary Conference. The Bureau is a technical international organization directly responsible to member states through technical representatives of those states. The original appropriation for the International Sanitary Bureau was \$5,000.00 per annum contributed by the various member states. Since 1924, the Bureau has grown tremendously and has undertaken increasingly important activities for the development of sound practices throughout the American Republics. On May 24, 1949, an agreement was signed between the World Health Organization and the Pan American Sanitary Bureau designating the Pan American Bureau as a regional office of the World Health Organization.

## THE HEALTH SECTION OF THE LEAGUE OF NATIONS

Considerable interest was evidenced in international health at the Paris Peace Conference and the need for a permanent operating agency in the international health field was recognized at a conference held in 1920 at which time the plan for the Health Section of the League was drawn up and adopted by the 1923 League Assembly. The Health Section was an integral part of the League of Nations and was not an autonomous agency. As set up by the League of Nations, it consisted of three major divisions: (1) a general advisory health council, made up of representatives of some 50 governments having membership in the League of Nations; (2) a standing health committee of 12 medical experts appointed as individuals and not as governmental representatives; (3) the secretariat of the Health Section, consisting of medical and health experts, not necessarily from member nations of the League of Nations, who were an integral part of the general League secretariat. The functions of the Health Section of the League of Nations consisted of the following:

1. **EPIDEMIC INTELLIGENCE.** This provided for notification of epidemic disease direct from the national health agencies to the secretariat of the Health Section and for direct communication between the secretariat and the national health authorities; thus, for the first time, epidemic disease notification did not have to pass through regular diplomatic channels. An office was maintained in the central headquarters in Geneva and an Eastern Bureau was maintained at Singapore. This gave a much more effective epidemic intelligence than had ever been developed on an international scale before.

2. **CONSULTATION SERVICE.** Consultation service was provided to all member nations upon request and a comparatively large and competent staff of consultants was developed which gave extensive service, particularly in Greece and in China. In the early years, very serious epidemics swept over a large part of Europe and the League carried on the activities of the epidemic commission. Under these auspices numerous expert committees in various epidemic disease problems were created. These special committees included commissions on malaria, smallpox, leprosy, and syphilis. These committees and commissions carried on research and planning for the control of these diseases. The importance of nutrition was recognized as a public health factor and studies were carried on in various parts of the world which stimulated interest in the improvement of general nutrition. Partly as a result of the activities of this section, a joint commission of the various sections, necessarily involved in the improvement of nutrition, was formed which carried out important studies of these problems throughout the world.

3. **INTERNATIONAL BIOLOGICAL STANDARDIZATION.** Recommendations for the creation of a laboratory for biological standardization were made and, in 1924, a permanent commission on biological standardization was established. Standardization of serums, vaccines, drugs, and vitamins was carried out in various selected laboratories throughout the world and the results of these standardizations were coordinated at the Serum Insti-



tute in Copenhagen and at the Hampstead Institute in England. The International Conference on biological standardization in 1935 set up two permanent commissions on biological and drug standardization—one for standards adopted for sera and bacterial products and one for standards for certain therapeutic substances, vitamins, and hormones. The standards established by these commissions were known as League of Nations Units. This work had a tremendous influence throughout the world in maintaining adequate and uniform standards of prophylactic and therapeutic products.

4. **EDUCATION AND TRAINING.** The Health Section embarked upon an extensive program of education and training in the health field. An extensive health and medical library was developed which was available to all nations upon request and was extensively used. The Section also developed a fellowship program providing for the training in public health of workers from all parts of the world. In addition to the support of the Rockefeller Foundation, extensive interchange of health personnel between various countries was made possible through travel fellowships.

5. **RESEARCH.** Through its expert committees and commissions the section actually carried out and stimulated extensive research in the infectious and epidemic diseases, nutrition, and health administration.

### THE UNITED NATIONS RELIEF AND REHABILITATION ADMINISTRATION

World War II created such extensive destruction of property and so completely disrupted normal activities and brought about such extensive displacement of persons, that it was early recognized that the postwar period would be fraught with great dangers, not only economic and social in nature, but also of tremendous health significance. The memory of the epidemics following World War I was still clear and the health organization developed between the two wars was almost completely destroyed. Recognizing the need for early action, the United States suggested in 1943 the development of an international relief organization. Forty-four nations met and set up the United Nations Relief and Rehabilitation Administration. Each uninvaded nation pledged 1 per cent of its national income for the year ending June, 1943, creating an initial fund of nearly two billion dollars. Extensive plans were developed for the relief of suffering in devastated countries, including the rehabilitation of medical and health services and the provision of medical supplies and facilities for epidemic control. Medical and health officers were recruited from all over the world and material and technical assistance was provided to the devastated nations to carry out extensive immunization programs and to re-establish national health services. Health missions were established in Western Europe, the Far East, Greece, and in Italy. An important activity of this administration was the handling of displaced persons in such a way as to prevent the spread of disease. UNRRA was responsible for the conference of public health experts, held in Paris in March and April of 1946, which developed plans for the international congress, held in New York in June, 1946, at which was drafted the constitution of the World Health Organization.

### WORLD HEALTH ORGANIZATION OF THE UNITED NATIONS

At the San Francisco conference in 1945, when the charter of the United Nations was drawn up, it was recognized that there should be an international health organization. In the following year, the World Health Conference in New York

drafted a constitution for the World Health Organization of the United Nations which was signed by all representatives of the nations participating. An interim commission was set up to develop the World Health Organization in accordance with the constitution, pending the necessary ratification by a sufficient number of nations. Ratifications having been obtained, the World Health Organization was formally established in September, 1948. WHO, as such, is a specialized agency of the United Nations. It is supported by the nations which ratified the constitution of the World Health Organization, regardless of their membership in the United Nations.

The purposes of the World Health Organization as defined in its constitution are:

1. To assist governments upon request in strengthening health services.
2. To promote improved standards of teaching and training in the health, medical and related professions.
3. To provide information, counsel and assistance in the field of health.
4. To promote, in cooperation with other specialized agencies where necessary, the improvement of nutrition, housing, sanitation, recreation, economic or working conditions, and other aspects of environmental hygiene.
5. To promote cooperation among scientific and professional groups which contribute to the advancement of health.
6. To promote maternal and child health and welfare, to foster the ability to live harmoniously in a changing total environment.
7. To foster activities in the field of mental health, especially those affecting the harmony of human relations.
8. To promote and conduct research in the field of health.
9. To study and report, in cooperation with other specialized agencies where necessary, administrative and social techniques affecting public and medical care from preventive and curative points of view, including hospital services and social security.

Health, as it is defined in the constitution of the World Health Organization, is "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." As the definition of health and the stated purposes of the World Health Organization indicate, this agency undertakes international cooperation in a much broader and yet a more specific sense than any previous international health organization.

The work of the organization is carried out under the direction of the World Health Assembly, which is composed of representatives from the member states. At the present time, there are 68 member states, although the U.S.S.R., the Ukraine, Byelorussia, Bulgaria, Rumania, Albania, Czechoslovakia and Poland have signified their wish to withdraw from the organization. There being no provision in the constitution for withdrawal, they may be considered as a nonparticipating group of members of the organization.

The assembly consists of official delegations from the member states who are usually accompanied by nonvoting technical advisors. Since the establishment of the organization, the assembly has met annually but it is proposed that in the future it might meet every two years. Direction is given to the operation of the organization between meetings of the assembly by an executive committee consisting of 18 members. The administration of the organization is through a director general, a deputy director general and staff. The major subdivisions of the organization are the departments of Central Technical Services, Administration and Finance,



Advisory Services and the Regional Offices. The Department of Central Technical Services comprises divisions of epidemiology, health statistics, therapeutic substances, editorial and reference services; the Department of Administration and Finance contains a division of administrative management and personnel and the division of budget and finance; the Department of Advisory Services has divisions of communicable disease services, organization of public health services and professional and technical education. Each division is broken down into sections dealing with specific public health problems.

The first World Health Assembly agreed upon the creation of six regional organizations to carry out the detailed functions of the World Health Organization in different parts of the world. These areas were: (1) eastern Mediterranean area with headquarters in Alexandria; (2) southeast Asia with headquarters at New Delhi; (3) the Americas (the Pan American Sanitary Bureau) with headquarters in Washington; (4) Africa, (not yet organized); (5) the Western Pacific (not yet organized); and (6) it was agreed that the Geneva office should serve as a regional office for Europe.

The first World Health Assembly selected a number of projects for the program of the organization. It was decided that first consideration was to be given to diseases which lend themselves to international action, and that the program should aim at the solution of health problems which exist in large areas of the world. On this basis, the following were selected as priority fields.

1. Malaria control.
2. Tuberculosis control.
3. Venereal disease control.
4. The promotion of health by such positive means as concentration on measures aimed at improving the health of mothers and children.
5. Amelioration of environmental conditions which until now have been responsible for a significant proportion of all deaths throughout the world.
6. The improvement of nutrition, an essential condition to the betterment of health for both children and adults.

The second World Health Assembly, held in 1949, specifically emphasized the role of mental health as an important component of the world health problem and authorized the development of health demonstration areas.

The budget of the World Health Organization for the first year after the establishment of the permanent organization (1949) was five million dollars. The budget for 1950, approved by the second World Health Assembly, was \$7,500,000.00 but a program was outlined for the organization requiring the appropriation of \$17,000,000.00. This was based on the assumption that approximately \$10,500,000.00 might be raised by voluntary contributions from member states willing to participate in the development of the program in underdeveloped countries. Unfortunately, not all of the member nations have contributed the full amount budgeted.

One of the most important functions of the organization is the provision of advisory services, which consist largely of:

1. Assistance to professional and technical education through assistance to educational institutions, provision of fellowships, the exchange of scientific information, and the distribution of medical literature and teaching materials.

2. Consultation and advisory service in specialized fields to medical and related subjects as requested.

3. Demonstration projects, particularly in underdeveloped areas.

These advisory services are offered to governments through the regional staff of the organization. In order that the advisory services might have available most complete knowledge in specialized fields, a number of expert committees have been created. These expert committees, composed of outstanding individuals in specialized fields from all parts of the world, meet to consider specific disease problems and to pool all available knowledge and to consider specific questions submitted to them. These reports are made available to all member nations. Through this mechanism WHO benefits by the advice of leading specialists from all parts of the world and these experts benefit from the exchange of ideas made possible through meeting with experts from other parts of the world. The following expert committees have been appointed:

Environmental sanitation, hygiene of seafarers, which is joint with the International Labor Organization; insecticides; malaria; maternal and child health; mental health; nursing; nutrition, which is joint with the food and agricultural organization; professional and technical education; public health administration; tuberculosis and venereal disease.

Special subcommittees have been appointed to deal with certain specific questions within the field of an expert committee, as, for example, in school health, problems of prematurity, the use of streptomycin in tuberculosis, etc.

One of the most serious problems faced by national health organizations throughout the world is the shortage of trained technical personnel. The World Health Organization has undertaken to provide advice and assistance in the development of training programs in various parts of the world. Assistance has been given in the development of educational opportunities in the fields of medicine, public health, nursing, nutrition, medical social work and related sciences. An important part of the program to improve professional and technical education is through its fellowship program. This fellowship program was begun under the Interim Commission and has continued and expanded. In selecting fellows, priority is given to those individuals who will be in a position to contribute most to their respective health programs and who will further the program of education through teaching upon completion of the fellowship period. One of the most important activities of the World Health Organization is the exchange of scientific information, which is carried out through the medium of the expert committees and through specific exchange programs. In addition to this, a program of seminars on special subjects has been arranged for personnel in a group of related countries. Upon request assistance is also given to the various countries for material aid in the development of library facilities, and the exchange of medical literature and teaching materials, such as film strips, slide projectors, charts, etc.

Because of the limited resources of the World Health Organization it was decided that the organization could not undertake to provide medical supplies to countries unable to obtain these because of currency problems, except in very unusual circumstances, such as the cholera epidemic in Egypt. The World Health Organization maintains close relationships with other United Nations specialized agencies, particularly the United Nations Children's Emergency Fund. Through



an agreement with this organization the World Health Organization provides medical and technical advice and directions to specific projects financed by the United Nations International Children's Emergency Fund. Nutrition projects are handled jointly with the food and agricultural organization, and activities in the field of occupational health and the hygiene of seafarers are conducted in cooperation with the international labor organizations.

Because of financial limitations, the Executive Board of the World Health Organization has set up the following criteria for the selection of projects under the advisory services:

1. Programs established by the World Health Assembly or by the United Nations and its specialized agencies.
2. Projects recommended by expert committees.
3. Problems of importance to the whole health program of the requesting country and inability of the country itself to provide the services required as measured by the availability of trained personnel.
4. The probability of achieving successful and useful results.
5. Assurance of participation and cooperation on the part of the government throughout the program, including contributions to the program by meeting such costs within the country as can be met with domestic currency.
6. Reasonable assurance from the government, where appropriate, that the program will be continued.
7. Equitable distribution among the various countries seeking assistance when the requests exceed the available budget.

A division of therapeutic substances was established in the World Health Organization; this division includes sections on biological standardization, unification of pharmacopoeias, drugs and drug addictions and coordination of research. All of these activities call for the pooling of knowledge and experience obtained in various countries and the development of standards of control measures applicable and acceptable to all governments. The section on biological standardization continues the work initiated in 1921 by the Health Section of the League of Nations. International standards have been established for a number of biological products which have been accepted by the majority of nations throughout the world. Continuing studies are carried out as to the efficacy of various biological products and a large number of national laboratories participate in the program of standardization.

The need for standardization in the field of therapeutic substances other than biologicals has been increasingly recognized. In 1947, the Interim Commission of the World Health Organization established an expert committee charged with the responsibility "to draft an international agreement for the unification of pharmacopoeias modifying and extending the existing agreement for the unification of all the formulae for potent drugs. To present the draft agreement as an international pharmacopoeia similar in form to the present national pharmacopoeias."

This committee has worked continuously since that time and is developing the first volume of an international pharmacopoeia. This volume will include drugs of an established therapeutic value common to the various national pharmacopoeias. The rapid advances in medical science will perhaps make it difficult to define fixed standards for many of the newer drugs, but the publication of such an international pharmacopoeia will be of great value in international health work.

The section on addiction-producing drugs carries on the work which was previ-

ously the responsibility of the Health Section of the League of Nations. This section is in L'Office Internationale d'Hygiène Publique. The expert committee on addiction-producing drugs made rather extensive studies of new synthetic substances and has tested the addiction-producing character of many of these new drugs. Standardization of the nomenclature is also an interest of this section. It is interesting that alcoholism has been included in the activities of this section, alcohol being recognized as an addiction-producing substance.

The division of health statistics maintains sections on statistical studies, morbidity statistics, and the international nomenclature of disease. This division continues the epidemiological intelligence carried out by the Health Section of the League of Nations and undertook the revision of the International List of Diseases, Injuries and Causes of Death which was due in 1948. The expert committee on health statistics considers matters pertaining to uniform presentation of statistical material, the definition of terms, such as stillbirths and fetal deaths, and maintains a continuing interest in classification of disease. This section is also available for consultation services for the development of more adequate statistical services in the national health program.

### BILATERAL INTERNATIONAL HEALTH ACTIVITIES

**The Institute for Inter-American Affairs.** The United States Government has upon occasion, primarily for political reasons, given assistance to less well developed nations in the organization of a health program. As a part of what was called the "Good Neighbor Policy," the United States Government established the Institute of Inter-American Affairs in 1942 as an emergency measure to assist in the development of Latin American Nations. Under this program, health needs were recognized and a health division was established to provide assistance to Latin American Nations in the development of a more adequate health service. This has been given both as technical advice and as financial assistance on a cooperative basis. This program was approved by a conference of Ministers of Foreign Affairs of the American Republics in January, 1942.

This body resolved:

1. To recommend that the governments of the American Republics take individually, or by complementary agreements between two or more of them, appropriate steps to deal with problems of public health and sanitation by providing, in accordance with ability, raw materials, services and funds.
2. To recommend that to these ends there be utilized the technical aid and advice of the national health services of each country in cooperation with the Pan American Sanitary Bureau.

Established as a temporary organization for a five-year period, the Health Section was continued at the end of the five-year period and the organization has recently been re-established.

### THE POINT FOUR PROGRAM

In his message to the Congress of the United States in June, 1949, President Truman called attention to the need for technical assistance to underdeveloped areas of the world and proposed that the United States should offer such technical



assistance, either directly or through the United Nations. As a result of the initiative of the United States, the World Health Organization prepared a supplementary budget for 1950, and again for 1951, for the utilization of funds which might be made available under the technical assistance program. The technical assistance program is not designed primarily to improve health work but only as health may contribute to the improvement of the economic level of the area concerned. The economic and social council of the United Nations has established a technical assistance board which has been active in drawing up the terms of reference for technical assistance programs and in stimulating member states to contribute to the fund proposed by President Truman. Approximately 20 per cent of the funds for technical assistance of the United Nations has been made available to the World Health Organization for health programs. In addition to the contributions by the United States to the United Nations, considerable sums are made available for bilaterally contracted programs. Under Public Law 535, the enabling legislation for the Point Four Program, provision is made for extensive technical assistance to underdeveloped countries in the development of health programs. This program is administered by the Department of State and the Economic Co-operation Administration.

#### UNITED NATIONS INTERNATIONAL CHILDREN'S EMERGENCY FUND

The United Nations International Children's Emergency Fund, which was created in December, 1946, by the General Assembly of the United Nations, is not an autonomous technical organization as is the case with the World Health Organization. It is directly dependent upon the General Assembly of the United Nations.

During its first three years of operation, this organization was allocated \$418,000,000.00, in large part through special appropriations made by governments. These contributions have come from 43 governments in various parts of the world, 24 of which receive aid from the same organization. The initial program of U.N.I.C.E.F. was confined to supplementary feeding of children in war-devastated areas. As resources increased and the emergency needs of these countries declined, the organization extended its field of operations to other countries and to programs stressing child health and maternal and child care. Through mutual agreement the World Health Organization gives technical advice to the U.N.I.C.E.F. medical and health programs. In certain areas of the world, where medical and technical staffs are not available within the World Health Organization, U.N.I.C.E.F. has developed a technical and health program.

## THE VOLUNTARY HEALTH ORGANIZATIONS

During the past half century there has been very rapid development of voluntary health organizations in the United States. These organizations have had a marked effect upon health services. For the most part, voluntary agencies are incorporated bodies of citizens interested in the improvement of some particular phase of health service. As philanthropic organizations they are tax-free and are financed by contributions or by special fund-raising devices. Their general purpose is to augment the services rendered by the official agencies and their functions vary according to the purpose for which they were established. The most commonly encountered functions are the following:

1. Direct service in the control of some specific disease.
2. Demonstrations to stimulate interest in certain health programs with the idea that, having been demonstrated to be of value, they would be provided by the official agency.
3. Public health education in a specific or generalized field.
4. Consultation in regard to a specific disease problem.
5. Support of the official agencies.

Many of the voluntary agencies began as direct philanthropies. As an example, the settlement nursing services were established to augment and make more effective material assistance rendered to the poor. Out of this grew a preventive nursing service which has become the public health nursing services of today. In this sense, the voluntary agency was a pioneering group, demonstrating the values of public health procedures which later were taken over, in part at least, by the official agencies.

Another example of the outgrowth of a primarily philanthropic activity was the baby milk stations or the baby milk funds developed in many cities. In providing for the poor, the urgent need for milk to supplement the diet of infants was recognized and these philanthropic agencies were set up to provide a safe quality of milk to the recipients of material aid. Since babies were brought to these milk stations to obtain the milk and were observed not only to be undernourished but also greatly in need of medical supervision, nursing and, eventually, medical services were added to the baby milk stations. They were the forerunners of the well-baby clinics of the modern health department.

### CATEGORICAL ASSOCIATIONS

**The National Tuberculosis Association.** Public-spirited citizens, observing the lag in the application of knowledge, organized voluntary health agencies devoting



their attention to the prevention of specific diseases. One of the first of these was the National Tuberculosis Association. The first tuberculosis association was developed in Pennsylvania and was known as the Pennsylvania Society for the Prevention of Tuberculosis. This Society, established in 1892, was apparently a great success. In 1904, there were some 23 tuberculosis associations or societies, and a group of prominent citizens, recognizing the need for public education and public support for more adequate treatment and prevention of tuberculosis, organized the National Tuberculosis Association. This organization has stimulated the development of associations in the 48 states and in a large proportion of the counties of the states. It adopted the Christmas seal sale as a means of providing financial support early in its history and this has proved a constantly increasing source of funds. There are some 3,000 local branches and the large bulk of the income from the Christmas seal sale is retained in the local communities to support activities for the prevention and the care of tuberculosis.

**The American Social Hygiene Association.** The American Social Hygiene Association, established in 1914, was a combination of a number of national and local societies interested in the prevention of syphilis and gonorrhea and, since its establishment, has been a potent influence in rousing public interest in, and support for, official programs of venereal disease control.

**The American Society for the Control of Cancer.** In 1913, the American Society for the Control of Cancer was established with the objective "to disseminate knowledge concerning the symptoms, diagnosis, treatment and prevention of cancer, to investigate the conditions under which cancer is found and to compile statistics in regard thereto." The society carried on a very limited program until recently when it was reorganized and has undertaken, through an extensive fund-raising campaign, to provide funds for research and education for the prevention of cancer.

**The American Heart Association.** In 1933, the American Heart Association was established by a merger of a number of other agencies interested in the study and control of this major cause of death. It, too, has within recent years been reorganized and has undertaken an extensive fund-raising campaign.

**The National Foundation for Infantile Paralysis.** The National Foundation for Infantile Paralysis, established in 1938 following a series of fund-raising campaigns in connection with President Roosevelt's birthday, has become one of the most successful of the voluntary agencies directing efforts toward a specific disease.

**Other Associations.** Numerous voluntary agencies have been created in recent years for specific diseases. Among these are the American Diabetic Association and the National Multiple Sclerosis Society. Other special interests have also been recognized in the formation of voluntary agencies, such as the National Society for the Prevention of Blindness, the American Society for the Hard of Hearing, the National Dental Hygiene Association, the Planned Parenthood Federation, and various associations for crippled children and mental hygiene. Many fraternal organizations, such as Rotary, the Shriners, Kiwanis, etc., also maintain health activities, particularly for crippled children.

The American Red Cross, while not primarily a voluntary health agency, carries on many fields of activity directly or indirectly related to public health. Within recent years the development of the national blood program represents a major

activity in the field of public health. It has also traditionally carried on both public health and bedside nursing services, and has maintained an extensive home-nursing training program. It also maintains a nutrition service, first aid and water safety programs, and accident prevention service. At the present time it has been assigned extensive responsibility in relationship to the civil defense, much of which involves health services.

There can be little doubt that the voluntary health agencies in the United States have been important in the development of general health services. These agencies augment and supplement the programs of the official agencies and have continuing important functions to serve, particularly in the field of public education and in demonstration of new methods of attack upon problems of disease and disability. On the other hand, certain dangers arise with the very rapid development of more and more agencies. There is need for some method of coordination of their activities in order to avoid competition, duplication and waste. There is also need for periodic evaluation of their programs. One mechanism which has been suggested is a voluntary interchange of ideas and joint planning through health councils or associations. At the national level this is attempted through the mechanism of the National Health Council, which is itself a voluntary agency with membership consisting of the majority of the national voluntary agencies. This council stimulates the development of local health councils, made up of local representatives of national and other local agencies, for joint planning and for well-rounded services in the community.

The extent of the services provided by the voluntary agencies is indicated by the sums of money contributed each year by the people of the United States. It is estimated that the contributions in 1950 for health purposes alone was well in excess of one hundred million dollars.

## THE GREAT FOUNDATIONS

Of great importance in the development of the health field, both in the United States and at the international level, have been the great foundations.

One of the first activities of The Rockefeller Foundation in the health field was the establishment, in 1909, of the Hookworm Commission. Out of this grew an extensive health program supported by the Foundation both in this country and abroad. Through its divisions, The General Education Board, The International Health Division and The Division of Medical Sciences, support has been given to programs for the control of many diseases, for the strengthening of health services in this country and throughout the world, for the improvement of medical education and for the support of training of public health personnel, both through the establishment of schools of public health and through a fellowship program.

The Milbank Memorial Fund has stimulated and improved public health practice through numerous demonstrations in this country and has supported basic studies in nutrition and demography. In recent years the Fund has given important support to the development of international health organization.

The Commonwealth Fund has also contributed greatly to the development of rural health services through research and demonstration, has carried out an exten-



sive program of rural hospital development and has financed studies on the quality of medical care and hospital services.

The Kellogg Foundation has carried on similar activities both in the United States and abroad.

### PROFESSIONAL SOCIETIES

Various professional societies related to public health make a very direct contribution to public health administration in the United States. The American Public Health Association, through its standing committees, carries on important activities for the improvement of public health. The Committee on Research and Standards evaluates new developments in the scientific field as they relate to public health and recommends standard procedures for the operation of health services. The publication of *Standard Methods* brings together in readily available form standard procedures that have been evaluated by experts in the various fields. The Committee on Professional Education establishes recommended qualifications for public health workers and has developed and improved methods for merit system examinations. Through this committee, the Association has established an accreditation system for schools of public health and for field training areas. The Committee on Administrative Practice carries on a program of research in administration and a system of evaluation of administrative practices.

The American Medical Association, through certain of its councils, has had an important influence on the general health of the country. The Council on Medical Education and Hospitals has, over many years, stimulated improvement in medical education through its program of accreditation of medical schools and has stimulated the improvement in teaching of preventive medicine. Through its program of approval of hospitals for internship and residency this Council has had a tremendous influence on the improvement of graduate medical education and of general medical services. The Council on Pharmacy and Chemistry has carried a valuable function in the standardization of therapeutic agents and, through its control over extravagant claims for therapeutic products, serves as a safeguard against the exploitation of the public. The Council on Foods and Nutrition has made important studies in the general nutrition field and has promoted standardization, particularly of vitamin products.

The American Dental Association, through its Council on Dental Health and Dental Therapeutics, has had an influence in improving general dental care and has stimulated the development of preventive services in health departments. Through its Council on Accepted Dental Remedies it has attempted to remove the dangers from the use of harmful dental products.

The American Hospital Association, through its Commission on Education, has stimulated interest on the part of hospital administrators in the development of a well-rounded public health service centered in the hospital.

These four professional associations, through the interassociation council, carry out joint planning in the general health fields. Other professional societies also have a direct influence upon development of health services. Important among these is the National Organization for Public Health Nursing, which carries out an active program of research and study in the fields of public health nursing and also serves as an accrediting agency for schools of public health nursing.

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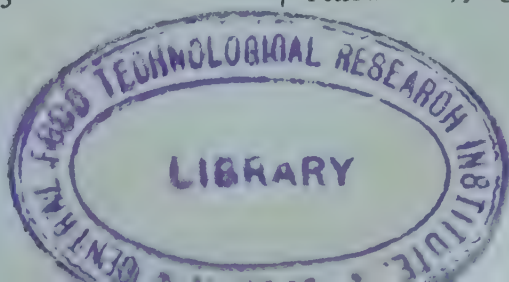
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